1959 Annual Report

LAKE STATES FOREST EXPERIMENT STATION
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

The Lake States Forest Experiment Station is one of nine regional forest research stations administered by the Forest Service, U. S. Department of Agriculture. It is maintained in cooperation with the University of Minnesota. Through Federal legislation, it is authorized to carry on forest research for the benefit of all forestry agencies in the region, including public forestry groups, wood-using industries, and other forest owners.

The territory in which the Station operates includes the Lake States (Michigan, Wisconsin, and Minnesota) and the Northern Great Plains. Besides the Station headquarters in St. Paul, field offices are located at East Lansing and Marquette, Mich.; La Crosse, Rhinelander, and Wausau, Wis.; Grand Rapids, Minn.; and Bottineau, N. Dak.

36 th ANNUAL REPORT

of the

LAKE STATES FOREST EXPERIMENT STATION

for the year 1959

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Introduction

With this 1959 Annual Report a significant decade of Station growth and development, unprecedented in the history of the Station, comes to an end. Now we reset our sights on the more troublesome problems and the greater opportunities of another decade.

During the fifties the research center organization took firm hold and moved forward in program activity. In the same period Stationwide programs were broadened to include the research projects in the fields of watershed management, forest utilization, and forest diseases and insects. Of special significance was the establishment in 1956 of the Northern Institute of Forest Genetics at Rhinelander, Wis., where emphasis is being placed on fundamental research relating to tree breeding, selection, and growth. Out of this tree improvement work should come some practical means for increasing the growth and quality of the major tree species in the Lake States.

Despite the many advances in knowledge of forestry and those that will come from research now under way, the forestry situation in the Lake States is far from satisfying. There are a number of problems that must be given greater attention. Coming to the forefront are basic questions concerning the maintenance of adequate habitat for wildlife. How, for example, are forests to be managed to ensure the necessary forage for sustaining deer herds while providing the necessary timber for meeting national wood requirements? Also demanding urgent attention is how to meet recreational needs for a "camping-minded," youthful population. Over one-third of the total population of the United States is within 1 day's driving distance of the forests and lakes of the Lake States region. The pressures of this population on the forests for recreation alone are so great even now that camping sites and facilities are inadequate, and further expansion without knowledge of people's needs will make the conflicts of multiple land use only greater.

Another problem, so obvious to foresters and so easily overlooked by others, is the 26 million acres of forest land producing little or no timber.

Included are about 8 million acres of land needing planting; the balance is poorly stocked and has species of low value and low quality. In no other forest region in the United States is the urgency greater and the job easier to get these idle acres back into production. Here investigations for more effective methods to obtain natural regeneration, lower cost planting methods, improved herbicides for destroying brush, and planting of selective and improved trees can make dollar expenditures go further--thereby paying for research many times over in increased wood production.

Looking to the sixties, one thing is clear. Timber losses from insects and diseases, now 10 times greater than from fire in the Lake States, are going to continue, and may even increase. In the last decade annual timber losses from these causes amounted to about 1 billion cubic feet, and this with a large proportion of our forest acres idle. Most serious in the years ahead may be the continued loss of timber quality because of the prevalence of heart rot in the hardwoods and the tendency for insect epidemics to develop in the growing acreage of coniferous plantations.

Before intensive forestry becomes an economic reality in the Lake States, timber losses from diseases and insects must be lessened. For this reason we have chosen in our 36th Annual Report to examine critically the forest protection situation and its related research needs.

Disease and insect research at the Lake States Station is relatively new. Only 6 years ago were these research activities, through Department reorganization, transferred to the Forest Service. Since that time, recognizing the critical need for research in these fields, program activity has more than doubled. Unfortunately, in the same period fire research has retrenched and is now at its lowest point in 25 years. Shortage of funds rather than lack of work has forced this retrenchment.

In addition to the emphasis on protection research, a few pages in this report highlight other significant Station developments in 1959.

At the back of the report an annotated list of the Station publications during the year is in itself informative as to the progress of the Station's program in 1959. Copies of most of the reports may be obtained by writing to the Lake States Forest Experiment Station, University of Minnesota, St. Paul Campus, St. Paul 1, Minnesota.

M. B. Dickerman

M. B. DICKERMAN, Director

1959 in Review

Progress this past decade in forest research has been apparent in numerous fields. Accompanying this progress, though, have been problems both in locating adequate laboratory facilities and in recruiting trained personnel. Currently the lack of research facilities at the Station headquarters in St. Paul and at field stations in Marquette, Mich., and Bottineau, N. Dak., are the most critical situations.

Some progress is being made at field locations in providing more space. At Grand Rapids, Minn., a new laboratory at the North Central Agricultural Experiment Station of the University of Minnesota will be ready for occupancy in 1960. At Rhinelander, Wis., a laboratory is being constructed for the Northern Institute of Forest Genetics. We will, however, be faced in 1960 with the problem of providing specialized laboratory equipment at these two buildings as well as related greenhouse and other facilities.

In recruitment and training of personnel, the progress in 1959 was most gratifying. The Station welcomed 10 new scientists during the year: Roland G. Buchman, Statistician; Donald H. Boelter, Soil Scientist; Kenneth J. Kessler, Jr., Plant Pathologist; Dean N. Quinney, Forest Economist; and Research Foresters Willie R. Curtis, Paul S. DeBald, Robert B. Hill, Thomas D. Rudolph, and Robert F. Wambach. James E. Sowder, formerly of the Pacific Northwest Forest and Range Experiment Station, was appointed Chief of Station Management. Leaving the Station were Robert A. Ralston, Research Center Leader at Wausau, Wis., who was transferred to the Central States Forest Experiment Station, and Loyd M. LaMois, who was transferred to the Forest Service Washington, D. C., office. Dr. J. H. Stoeckeler, awarded a Senior Postdoctoral Fellowship by the National Science Foundation, is in Europe for a year's study of bog and swamp hydrology, including afforestation and drainage effects; this information can be tested for applicability in this area. About 20 other staff members took special courses in statistical analysis, technical writing, or administrative management. In addition, the Divisions of Forest Management and Watershed Management each held staff meetings to discuss programs and exchange information.

Research accomplishments in 1959 reflect the acceleration of our program during the past few years. Some of the protection work is discussed in detail in the body of this report. Other work is commented on very briefly below.

Progress on inventorying and analyzing forest resources took many forms. Forest statistics for the first group of counties in Missouri are now being computed. In cooperation with the University of Missouri, the survey in the heavily wooded southern counties has been so intensified that we can report estimates of the timber resources by individual counties. In the Lake States, the Station sponsored a series of meetings of Federal, State, and industry inventory specialists to coordinate subject matter

covered in the various independent surveys and to standardize definitions. From these conferences and from the results of a national meeting of Forest Survey and Timber Management men held in November, materials were drawn to form a new Forest Survey plan for the Lake States. This plan, now being tested in Koochiching County, Minn., goes well beyond previous efforts to integrate the results of surveys made by different owners.

As a part of the Station's program to discover ways of promoting the acceptance of forestry programs and practices by the many small woodland owners in the region, a report on the characteristics of forest landowners in central Wisconsin has just been published. A similar study was begun in Upper Michigan, and one in the southern part of Lower Michigan is nearing completion.

Interest in forest taxation problems is increasing. A report on the relative impacts of taxation under the Forest Crop Law and the General Property Tax on net income from Wisconsin forest properties is ready for publication. A second study now under way will attempt to devise a more equitable system of land classification for tax assessment purposes, based upon market values of timberland as reflected in land sale data. The Wisconsin Conservation Commission is cooperating on both studies.

In marketing research, an analysis of wood used by Twin Cities manufacturing industries was published during the year, and a recanvass of charcoal marketing in Wisconsin will be reported early in 1960. The Station also helped with a report on "The Feasibility of Using Lake States Hardwoods for Newsprint and Other Pulp and Paper Products," published by the Washington Office of the Forest Service.

The annual survey of pulpwood production shows an increasing use of hardwoods by Lake States pulpmills. This shifting of the utilization picture indicates that more detailed reports would be helpful both in assessing the impact of cutting on present pulpwood supplies and in projecting future supplies. The Station is asking Lake States pulpmills to cooperate by furnishing pulpwood receipts by counties so that more specific comparisons of cut, allowable cut, and growth can be made.

Forest utilization research reached limited objectives in two major fields and made progress on all active projects during 1959. The initial phase of a long-range program of timber-quality research begun in 1955 was brought to near completion this year with a manuscript on methods for collecting and analyzing timber-quality data for tree value determination; the report on this project is now being reviewed. Fieldwork using these techniques and procedures to determine a tree-grading system for sugar maple will start in early 1960. Maximum use will be made of color photo techniques to record wood-quality features revealed by stem dissection. This initial methods-and-techniques study has shown that the many qualitative tree stem characteristics can be expressed numerically and evaluated in a mathematical prediction equation; the analysis is adaptable to electronic computers.

The experimental fieldwork on charcoal production in small kilns was completed in late 1959. It covered tests of four experimental kilns and scores of test burns to evaluate important variables of structural design and materials, form and condition of wood raw material, and operation. Analyses of test results are being prepared for publication. Any further charcoal research work will give emphasis to integrating charcoal-wood harvesting with forest management and silvicultural objectives of timber utilization.

Other studies are providing valuable leads on the role of the forest in watershed management. Early results in soil moisture behavior show that conifers and hardwoods have different patterns of water use. Aspect and topographical position are also important factors. Snow behavior under different forest types and cutting patterns indicates how timber management practices such as thinning, cutting methods, and type conversion can be used to affect snow behavior. Studies of ground freezing show that forest cover and its underlying humus influence the type of freezing which, in turn, determines the rates of infiltration during the critical spring melt period. Analyses of lysimeter studies indicate that the amounts of water which percolate to ground water also vary by cover type. These and results of other experiments are reported in two Station Papers and several articles and notes in professional journals.

A guide to management of seed production areas was published by the Station as part of the activities of the Lake States Tree Improvement Committee. Assistance was given to the national forests of the region in selection of such areas and their improvement through removal of less desirable trees. These stands of above-average timber will provide seed for use in Federally owned nurseries. Other land-managing agencies are taking similar steps to improve the parentage of planting stock. This outgrowth of the research program is a forerunner of broader application of information from genetics research.

Work on the genetic improvement of shelterbelt trees was strengthened through assignment of a staff member full time to this line of research. Severe temperature and moisture stresses in the Northern Plains kill or damage the less hardy plants in field trials. Variation within a species may be quite striking. Selection and controlled breeding will be aimed at producing hardy plants with superior growth characteristics.

Growth studies in red pine have long been a part of our forest management program. During the past year a summary of red pine growth data was completed for all of the Station's growth plots. Results now being readied for publication provide a strong base for thinning practices. Within a basal area range of 70 to 120 square feet, growth in cubic volume was found to be reasonably uniform. This confirms and strengthens previous less comprehensive research and the recommendations based on it. In the lower stand densities growth is concentrated on fewer trees, thus producing larger trees at younger ages. Value for wood production mounts rapidly with increasing size, so volume alone does not tell the whole story. Study

areas will be maintained to provide more data on tree size relationships and to broaden coverage of the range of site productivity.

Additional information on these activities and the many other studies under way can be obtained through our main office in St. Paul or through the Research Centers listed on the first page of this report.

Forest Protection

The catastrophic fires in the last half of the nineteenth century and the first three decades of the twentieth were so impressive in area covered, timber destroyed, and lives lost that, until very recently, forest protection has been practically synonymous with forest fire control. In more recent years, however, it has gradually taken on a broader meaning, even for the layman with only slight acquaintance with forestry problems. Forest protection now means protection against insects and disease as well as fire.

How has this change come about? Well, for one thing, the development of effective fire control organizations, coupled with the results of research on presuppression, detection, and control, has reduced the annual number of fires in the Lake States from around 10,000 to 3,000 and the mean annual burn from over a million acres to less than 100,000. These decreased losses from fire make those from insects and disease loom larger.

Furthermore, although no overall data on insect and disease damage are available prior to 1952, losses have probably increased over the years because changing conditions have made our forests more susceptible to attack. We have more young natural stands, more plantations, and more of the postfire types--aspen, jack pine, and balsam fir; all of these are more subject to attack than the former virgin stands. Logging slash and logging injuries encourage bark beetle and borer attack in the surrounding stands. Foreign insects and diseases have been introduced. And finally the demands of the burgeoning pulp and paper industry have made us more conscious of the economic losses.

The annual damage by fire, insects, and disease is enormous. In 1952 it was estimated at 850 million cubic feet in all growing stock and 2.7 billion board feet in sawtimber. Without these losses, net growth would have been approximately doubled. Not included in these figures are nursery losses of many hundreds of thousands of trees, reduction in timber quality, and, in the case of fire, site deterioration, which leads to inferior species composition and the loss of pleasant recreation areas.

The fire loss is small compared to that due to insects and disease; this of course shows the effects of an efficiently operating protection organization. It takes no account of the fact that relaxation of vigilance even for a day may lead to disastrous losses such as the fires this year at Badoura, Minn., and Webster, Wis., each of which burned over 15,000 acres, much of it in plantations. Neither does it consider that fire risk is constantly increasing because of both the ever-growing use of the forests for recreation and the annual increase in area of high-risk conifer plantations.

The following pages review the past history and problems relating to each of these destructive agents, the conditions leading to the present situation, some of the current research and needs, and future plans. A selected list of Station publications on forest protection appears on pages 54 to 57.

F O R E S T I N S E C T S[1/]

Forest Insect Damage Is a Longstanding Problem

Forest insects are a constant menace to the present and future wood supply in the Lake States. Epidemic outbreaks in the past have killed enormous amounts of timber. The Timber Resource Review showed that in 1952 insects killed more timber nationwide than did any other agency. Although mortality due to these pests was minor in the Lake States during that year, the possibility of heavy future mortality was already evident.

Furthermore, insect damage is not confined to mortality losses. Frequently infestations slow up growth, retard regeneration, result in tree deformity which reduces wood quality, and transmit diseases or make the trees more susceptible to them.

Historical records of insect damage are scanty. Some information, however, is available on the more severe outbreaks.

The forest tent caterpillar seriously damaged aspen stands in northern Minnesota in the 1890's. The larch sawfly killed practically all the mature tamarack in Minnesota between 1910 and 1926, the loss being estimated at 1 billion board feet. The spruce budworm outbreak between 1912 and 1926 resulted in a loss of more than 20 million cords of merchantable fir and an appreciable amount of spruce--almost a total loss since little if any salvage was undertaken. Many more localized or less serious epidemics have occurred such as the hemlock looper outbreak in Wisconsin and Upper Michigan from 1925 to 1928.

Insect damage in the northern hardwood types has become economically important only recently. Much of the acreage in these types has been a mixture of various species of hardwoods, often including conifers such as

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1/ Forest insect research at the Lake States Station is set up as a Division program. Dr. H. J. MacAloney is the Division Chief. His staff at St. Paul includes J. L. Bean, Dr. H. G. Ewan, D. C. Schmiege, and L. F. Wilson. Additional staff is located at the East Lansing Research Center and includes Dr. W. E. Miller, H. J. Heikkenen, and R. L. Talerico. H. O. Batzer is located at Grand Rapids, Minn.

hemlock. Apparently this mixed forest condition is not as susceptible to catastrophic insect damage as are the large-acreage, single-species types.

Currently the mature forests as well as the forest plantations are under severe attack. The spruce budworm, for example, has been in outbreak status in Minnesota since 1954. By 1959 moderate to heavy feeding was observed on nearly 1 million acres of spruce-fir type. Top killing and some mortality of balsam fir have occurred along the Canadian Border. There is no evidence that this outbreak is subsiding; instead it may be increasing in severity. The drain on our wood supply through growth loss alone will be considerable.

The jack-pine budworm has appeared in sporadic outbreaks during the past 35 years. Severe defoliation occurs for 3 or 4 years and, until natural factors cause a decline in an outbreak, results in top killing and reduced diameter growth. Tree mortality has occurred in young pole stands and in reproduction.

Although tamarack is not presently considered a high-value species, depredation by the larch sawfly is still cause for alarm. Past experience has shown that this insect can cause a staggering loss of trees with subsequent ill effects on watersheds. The current epidemic has spread over all three of the Lake States, and tree mortality is increasing in northern Minnesota.

Periodically the forest tent caterpillar causes noticeable defoliation over the vast aspen type in the Lake States; sugar maple in Michigan has also undergone heavy feeding. Severe defoliation for several years will reduce increment measurably. It apparently will also hasten death of overtopped trees already weakened by competition, or of trees in the upper canopy growing on poor aspen sites; but tree mortality solely attributable to feeding has not been noted on the better aspen sites.

Jack pine severely defoliated by the jack-pine budworm, Chequamegon National Forest, Wisconsin.

Red-headed pine sawfly; colony of full-grown larvae on red pine branch, Iron County, Michigan.

The major effort directed toward reforestation since the time of the Civilian Conservation Corps has created an ideal habitat for several very destructive forest insects. Workers have long agreed that relatively large, even-aged plantations offer a very favorable environment for sawflies, weevils, shoot moths, spittlebugs, and various other insects. Within the past decade the European pine shoot moth has become established in Michigan and southeastern Wisconsin where extensive plantations of red and Scotch pines are in danger of obliteration. Also, in the last decade over 100,000 acres of red and jack pine plantations have been aerially sprayed to prevent damage by the Saratoga spittlebug. The white-pine weevil continues its destruction of form and quality in white and jack pines, and more recently it has increased significantly on red pine and white spruce. Since an effective and economical control, such as aerial application of small dosages of insecticides, is still lacking for both the white-pine weevil and the European pine shoot moth, the importance of these insects will probably increase. Sporadic outbreaks of the red-headed pine sawfly and other sawflies are a constant threat to pine plantings--especially those established for the Christmas tree market. Many other species of insects have become at least locally destructive in the ever-expanding forest plantations of the Lake States.

This alarming increase of certain species of forest insects following the establishment of plantations points up the intimate relation between other changing forest conditions and the buildup of various pest populations.

Insects and Forest Conditions Are Interrelated

The interrelations of insects and forest conditions are expressed in many different ways. Perhaps most important, the composition of the forest may be radically changed by insect activity. Cone insects, for example, may destroy a very large proportion of the seed crop of desirable conifers

and permit the development of less valuable trees. Nearly pure balsam fir stands have succeeded the true spruce-fir type in some areas following spruce budworm outbreaks. Natural successions have also been accelerated. For example, natural deterioration of aspen stands may be speeded up by forest tent caterpillar defoliation; understory balsam fir then becomes the dominant species.

Fire often has indirect effects on insect populations. Fire-killed and fire-scorched trees attract many species of insects, chiefly bark beetles and borers, from considerable distances. Broods of these insects riddle the sapwood of the trees and, with the entrance of wood rots, quickly degrade them for lumber purposes. Many trees that might otherwise have survived the fire are killed by these insect attacks. On the other hand, stands killed by insect epidemics, such as the spruce budworm, and not salvaged immediately may be a fire hazard for several years. Although the dead trees begin to break up in a relatively short time, they become a tangled mass; lightning striking one of the few trees that remain standing results in widespread fires very difficult to control. Old insect-killed snags increase fire control costs since they should be felled as a fire prevention measure.

Weather may also cause drastic declines in insect abundance. In 1938 and again in 1959 a forest tent caterpillar outbreak in northern Minnesota collapsed following a late spring cold spell that delayed leaf development after the young larvae had emerged from the eggs. Low temperatures, either in the fall or in the spring, have reduced populations of the European pine shoot moth to a degree where projected control operations could be cancelled. Similarly late spring frosts, or high temperatures with low humidity, have decimated Saratoga spittlebug nymphal populations and made possible the cancellation of control projects.

Insects are frequently associated with various diseases and wood rots. The Dutch elm disease and oak wilt are two familiar examples of insects acting as direct vectors. While the economic significance is usually not well understood, insects are at least indirectly associated with many other diseases, rots, decays, and stains. For example, a number of insects infesting the boles of aspen trees may provide infection courts for Hypoxylon canker. Bark beetles and wood borers loosen the bark of dead trees or of logs and pulp stocks left in the woods or yard; this permits the development of sap rots and, to some extent, heart rots, which hasten the deterioration of wood quality. Armillaria root rot, bark weevils, and bark beetles can work together in hastening death of young trees, especially in plantations which have been weakened by some other agency. The webworm and leaf rollers appear to be associated with maple wilt, which has killed a large volume of sugar maple in northeastern Wisconsin in recent years; the relationship between these insects and maple wilt is being investigated by the University of Wisconsin.

Slashings left after logging operations tend to attract certain insects and cause a rapid population buildup. Among these are the bark beetles

and the borers; large broods can develop, and often the residual trees or those in nearby stands will be killed. For example, stands with a preponderance of paper birch or yellow birch are subject to postlogging decadence, aided very materially by bronze birch borer attacks. For these reasons, birch stands when logged should either be given only a light partial cut or be clear cut.

Weather plays a continuous role in the regulation of insect abundance. The severe droughts in the 1930's, along with defoliation by the jack-pine budworm and the jack-pine sawfly, killed a substantial amount of mature jack pine in parts of the Chippewa National Forest, Minn. About the same time much of the overmature hemlock on the Menominee Indian Reservation in central Wisconsin was windthrown. Tremendous populations of the hemlock borer developed in this windthrown timber before it could be salvaged, and attacked and killed many of the standing trees already weakened by drought. Armillaria root rot developed in the roots of many trees and hastened death. By 1938 these combined factors killed about 135 million board feet of merchantable hemlock.

Damaging Insects Are Found in All Forest Types

Lake States forests may be classified into four major forest types although many local types and numerous other combinations are recognized. Plantations and shelterbelts can be considered as another group. Within these groups more than 50 tree species occur in pure or mixed stands. Each has its complement of insects. The following table lists some of the more important species, their hosts, and type of injury.

Major forest type	Insect	Major hosts	Type of injury
Aspen-birch	Forest tent caterpillar	Aspens, birches	Defoliation
	Poplar borer	Aspens	Boring
	Bronze poplar borer	Aspens	Boring (secondary)
	Bronze birch borer	Birches, aspens	Boring (secondary)
Hardwoods (including hemlock)	Forest tent caterpillar	Sugar maple	Defoliation
	Walkingstick	Oak, basswood, cherry	Defoliation
	Leaf rollers and webworm	Sugar maple	Defoliation
	Hemlock looper	Hemlock	Defoliation
	Hemlock borer	Hemlock	Boring (secondary)

Major forest type	Insect	Major hosts	Type of injury
Spruce-fir	Spruce budworm	Balsam fir, spruces	Defoliation
	Larch sawfly	Tamarack	Defoliation
	Larch casebearer	Tamarack	Defoliation
	Cone insects	White spruce	Destruction of cones and seeds
Northern pine	Jack-pine budworm	Jack pine (red and white pines when in understory)	Defoliation
	Sawflies	All pines	Defoliation
	White-pine weevil	White and jack pines	Tip injury
	Pine tortoise scale	Jack pine	Sucking insect
	Pine root collar weevil	Jack and red pines	Girdling of root collar
Plantations	Sawflies	All pines	Defoliation
	Pine chafer	Jack pine	Defoliation
	White-pine weevil	All pines, Norway spruce	Tip injury
	European pine shoot moth	Red and Scotch pines	Tip injury
	Zimmerman pine moth	Red and Scotch pines	Tip injury
	Jack-pine shoot moth	Jack pine	Tip injury
	Pine root collar weevil	Jack, red, and Scotch pines	Girdling of root collar
	Saratoga spittlebug	Red and jack pines	Sucking insect
	Pine tortoise scale	Jack and Scotch pines	Sucking insect
Shelterbelts	Sawflies	Conifers	Defoliation
	Caterpillars	Hardwoods	Defoliation
	Caterpillars	Boxelder	Tip borers
	Caterpillars	Pines	Tip injury
	Borers	Green ash	Stem injury

Basic Studies Are a Necessity

The ultimate objective of applied forest insect research is the prevention or control of each insect epidemic that threatens the forest. Despite the success of modern organic insecticides, there is no panacea for insect problems. Attempts to apply chemical control without a thorough knowledge of the pest species and hosts involved and the possible deleterious side effects are economically and biologically presumptuous--if not dangerous. Each pest species must be meticulously investigated; the more complete our knowledge of the biology, ecology, and host relations of an insect, the greater our chances of effecting a biologically selective and economically sound control.

Methods of studying forest insects vary with the species in question. A pat technique with methods of investigation outlined in detail is neither possible nor desirable. The overall procedure, however, in studying a forest insect follows the general steps of most scientific investigations: (1) Defining the problem--a clear understanding of the problem is prerequisite to meaningful experimentation; sometimes, too, careful attention to this step will reveal that the problem is artifactual or trivial, (2) searching the literature--6 hours in the library may obviate 6 months in the field, (3) constructing an hypothesis; that is, a guess or proposition advanced as a possible explanation or solution to the problem, and (4) testing the hypothesis; included here are the actual design of the experiment, field or laboratory work, analysis of the data, and drawing of conclusions or recommendations.

Forest insect research may include three fields of investigation, each of which provides information leading to the ultimate objective--control.

Biological investigations.--Unless an insect's identity and life history are understood, control recommendations cannot be formulated. Years of research are sometimes required in these fields before certain problems are solved. For instance, the spruce budworm and the jack-pine budworm were long thought to be a single species, individuals of which fed on spruce-fir and jack pine. Taxonomic studies have recently revealed that these are actually sibling species with little or no interbreeding or host changing. Thus, control methods for the two species must be developed separately. Knowledge of life histories is obviously prerequisite to the development of control methods. One must know what life stage is most susceptible because of feeding activities, etc., or what stages, if any, are cryptic or resistant. Such information is also necessary to make accurate detection or evaluation surveys and to ensure the correct timing of control.

Ecological investigations.--The greater our understanding of the relations between an insect pest and its environment, the better our chance of discovering a weak link. A large part of forest insect research is devoted to ecological investigations. Biological control agents, silvicultural

Through biological studies we can determine the effect of natural control factors.

control practices, and even microclimatic conditions can sometimes be manipulated in such a way as to effect at least a degree of control on the insect pest. Furthermore, by understanding the population dynamics of a forest insect, we are better able to recognize various environmental conditions that are conducive to epidemics, and thus not be caught completely unaware of potentially dangerous situations. A familiar example of the recommendation that can be made from ecological studies is the removal of overmature balsam trees in order to make the environment less favorable for spruce budworm buildup. Methods of preventing or limiting attack by some species through proper tree planting practices have also been developed. Biological control, which has fired the imagination of many investigators, could eventually become a major means of combating forest insects.

Insect-host studies.--Generally speaking, these studies are also ecological in nature but, for convenience, are separated from the above. Included here are studies of actual or potential damage to the host tree or forest type by various populations of a pest, methods of surveying the degree of infestation by damage appraisal, resistance or susceptibility of various hereditary lines of the host, and effects of changing tree vigor or stand conditions on the insect. Generally, these studies involve at least several seasons of field observations under various test conditions. Practical information on efficient survey methods as well as on silvicultural practices designed to prevent or suppress attacks frequently emerge from these studies. A long-range investigation of the effects of various cutting practices in the spruce-fir type on budworm populations is discussed elsewhere in this section.

Some Significant Results Have Already Been Achieved

Federal forest insect research in the Lake States began in 1932 with a study of white grubs in nurseries and newly established plantations. This cooperative project, carried out at Cass Lake by the Forest Service, the Civilian Conservation Corps, and the University of Minnesota, was completed in 1936.

From 1938 to 1940 Secrest conducted intensive research on the hemlock borer on the Menominee Indian Reservation in central Wisconsin. A complete though unpublished report in the Station files discusses the biology, ecology, and natural control factors. This research showed the secondary nature of the insect itself following blowdown damage, drought conditions, and stand overmaturity, and resulted in revising hemlock management practices on the Reservation.

MacAloney, in 1941, investigated the decadence and mortality of mature jack pine in northern Minnesota. His research showed that it was caused primarily by drought conditions and high temperatures from 1936 to 1939. Defoliation by budworms and sawflies at the same time increased the damage. Suggestions were made for management of jack pine on a shorter rotation to prevent decadence.

Intensive studies of three especially damaging insects in the Lake States have resulted in the preparation of technical bulletins on each describing their biology, ecology, and control. One of these, concerning the red-headed pine sawfly and authored by Benjamin, was published in 1955 and is available at the Station. The second presents results of studies of the larch sawfly begun by Butcher in 1947 and continued by Drooz from 1951 to 1956; this bulletin is in press and should be available within a few months. The third summarizes research on the Saratoga spittlebug begun in 1941 when the insect was reported for the first time on red pine and jack pine in Wisconsin and Lower Michigan. This bulletin was prepared by Ewan and puts considerable emphasis on the development of workable evaluation surveys; it is now undergoing final revision.

Other studies of smaller scope have been pursued during these years, and results have been published by the Station or in various professional journals.

Current Research Covers a Few of the Most Pressing Problems

Because of the great damage potential of the spruce budworm, as witnessed during past outbreaks, a major portion of our research program is directed toward this pest. Headquarters for these studies are at the Kawishiwi Field Laboratory, near Ely, Minn. Another major effort is being made in studies of plantation insects, especially the European pine shoot moth. Preliminary studies of aspen stem borers, cone and seed insects, and pulpwood borers are also under way. Refinement in the accuracy and economy of forest insect surveys is a continuing effort in all the studies.

The results of research often transcend the discrete areas in which they were obtained. For instance, a technique for estimating the damage potential of a specific plantation insect may be more broadly applied to other pest and host species. In actual practice, however, a research project is usually carried out on a specific insect and host. Therefore, in order to present a brief and coherent account of the current research, the following discussion deals separately with each insect that is being actively studied.

Biology and Ecology of the Spruce Budworm

In 1955 a research program was initiated with two major objectives: First, to learn the natural history of the budworm in the Lake States, and second, to determine the potential value of various natural control factors and means for increasing their effectiveness. In these studies it was deemed desirable to always consider the possible influence of different stand compositions. Also, in actually gathering the data, the various individual studies were integrated--that is to say, information gathered on one aspect of the study is often supplementary to, or influenced by, data collected during other parts of the work. During the last 4 years much has been learned of the natural history of the larvae and the measurement of their development in the field. This information has been valuable in organizing control operations. Rearings of field-collected budworms have revealed over 20 important species of native parasites. Two of these species are new to science.

In all insect species, parasites are one of the major factors tending to prevent an endless population increase. However, the continued population growth of the spruce budworm in northern Minnesota shows that natural control factors have not reached an economically significant level. Although no conclusive results have been obtained in attempts to increase the effectiveness of the parasites, it is possible that cutting practices designed to reduce the amount of desirable budworm host material may reduce the budworm population--at least somewhat. This in turn may allow the unaffected parasite population to increase its attrition to the point where the budworm population is under control.

Spruce budworm epidemics do not usually develop in young, thrifty balsam fir.

The Spruce Budworm in Relation to Host Conditions

Studies of past outbreaks in the Northeast suggest that certain cutting practices may produce budworm-resistant stands. It has long been agreed that budworm larvae in endemic populations and beginning outbreaks must overwinter in the staminate flower bracts which occur in abundance on overmature balsam fir. Thus, the development of a budworm epidemic may be prevented by cutting methods which remove these overmature trees and which can be carried out at costs not much higher than normal harvesting costs. Tests to check the validity of this hypothesis have never been completed. Therefore, such studies have been initiated with relatively large sample plots (about 25 acres). The budworm population and subsequent host damage are measured on the plots, each representing various conditions of stand composition, individual tree characteristics, and harvesting methods. Already it can be stated that in comparable stands the defoliation is heavier in uncut blocks than in partially cut blocks.

Differentiation of Mortality Due to Spruce Budworm and That Caused by Other Factors

Whenever an insect epidemic subsides and an account of the damage is attempted, it is generally difficult to allow for the trees that died primarily for reasons other than insect attack. To help resolve this problem, several plots have been set up for yearly insecticidal control to prevent budworm damage. Tree conditions in these sprayed plots will be compared with the check plots from similar stands. So far, defoliation has been successfully prevented, and the trees appear normal and healthy. In the check plots, repeated heavy defoliation has already caused some top kill.

European Pine Shoot Moth Studies

Research under way in Lower Michigan since 1956 has made notable advances in chemical, biological, and cultural methods for preventing or controlling damaging European pine shoot moth infestations in young pine plantations. The biology of the insect, through basic laboratory and field studies, has also received much attention, because more precise information is needed to supply the needs of advancing control technology.

Several new insecticides, already screened by the State of Michigan and other Federal agencies and found promising, have been field tested in Lower Michigan. This year, during the spring and summer treatment periods, Trithion, Delnav, and Guthion were applied to red pine plantations by row-crop mist blower. Trithion gave the best results: At 2 pounds per acre (in 50 gallons of water) on trees 4 to 6 feet tall it equalled the effectiveness of the standard DDT treatment, and cost only about half as much. Trithion also prevents mite and aphid buildups, which DDT permits, but is more hazardous to man and to wildlife. These tests will be continued for further evaluation.

To date, native parasites in problem areas in Lower Michigan have caused little or no important reductions in shoot moth populations; by contrast, parasites play an important role in reducing populations in Europe. A

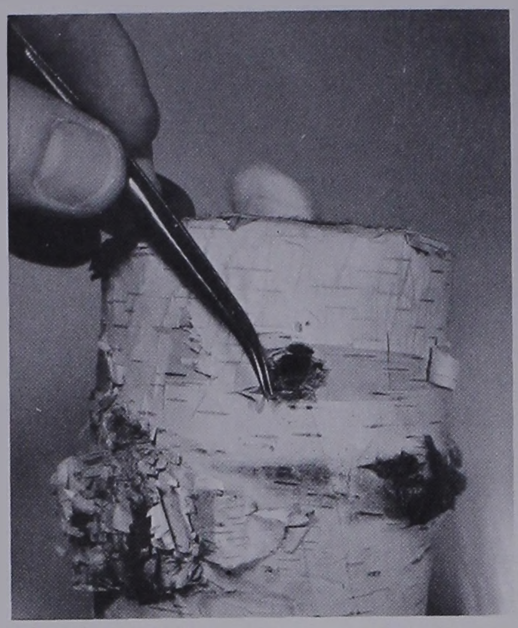
Red pine trees of low vigor (left) are more heavily damaged by the European pine shoot moth than are trees of high vigor (right).

survey in 1958 showed that one of these, Orgilus obscurator, previously released in Ontario, had spread naturally as far as the central part of the Lower Peninsula. This prompted a stepped-up program for releasing foreign parasites, and in 1959 a shipment of obscurator, from Switzerland, was released in the western part of the Lower Peninsula, where it has not been found. Periodic checks will be made to determine establishment and to learn more about rate of spread and buildup. Evaluation studies will also be made to assess its importance as a suppression agent.

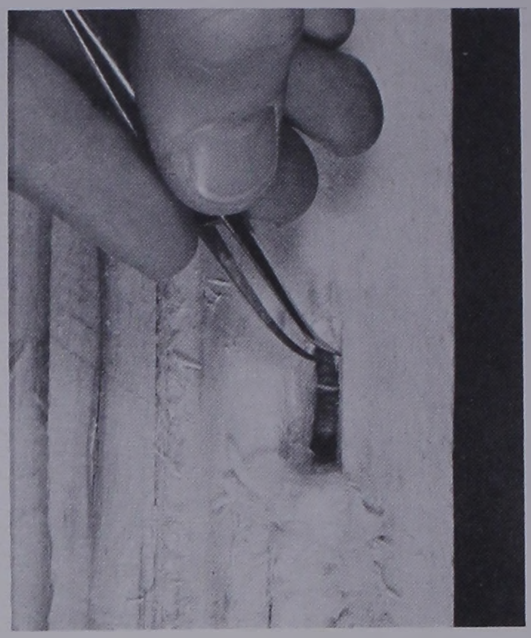
The improvement of stand conditions is another line of research currently active. It was prompted by the general observation that trees poor in vigor are especially susceptible to damage while those of high vigor are usually resistant. Analyses of the soil and of red pine foliage have indicated that mineral deficiencies accompany much of the low vigor associated with heavy shoot moth damage. Therefore, in the spring of 1959 plots were set up in three Lower Peninsula plantations to study the effects of several rates of complete fertilizer applications on tree growth and damage. Favorable tree responses were already evident in the fall of 1959, and the stage is set to determine the effect this response will have on attack by the insect and degree of damage.

Poplar borer larvae artificially established in:

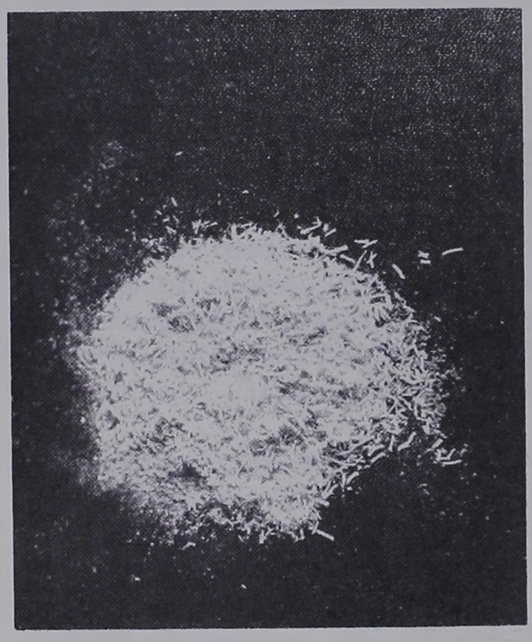
dry birch section



dry largetooth aspen



Birch excelsior



Aspen excelsior

Aspen borers; development of larvae in aspen and in birch. The two lower pictures show excelsior-like material resulting from tunneling.

Ecology and Damage Potential of the Aspen Stem Borers

The qualitative impact of the aspen stem borers, of which the poplar borer (Saperda calcarata) is the most important, is threefold: (1) Direct wood loss and subsequent windthrow result from larval tunneling, (2) rots and decays are introduced into the trees, and (3) infection courts may be provided for the Hypoxylon canker disease. Two years' preliminary research has proved that quantitative solutions to the problems will be difficult. Analysis of 166 plots, established 10 years ago in the northern part of the Lake States to collect data on Hypoxylon canker, has yielded interesting information on prevalence of attack by the poplar borer. For example, the heaviest infestations are in stands with the larger average diameters at breast height. Moderately stocked stands are more heavily attacked than either well-stocked or very poorly stocked stands. No simple relation has yet been found between the occurrence of Hypoxylon canker on these plots and the incidence of stem borers.

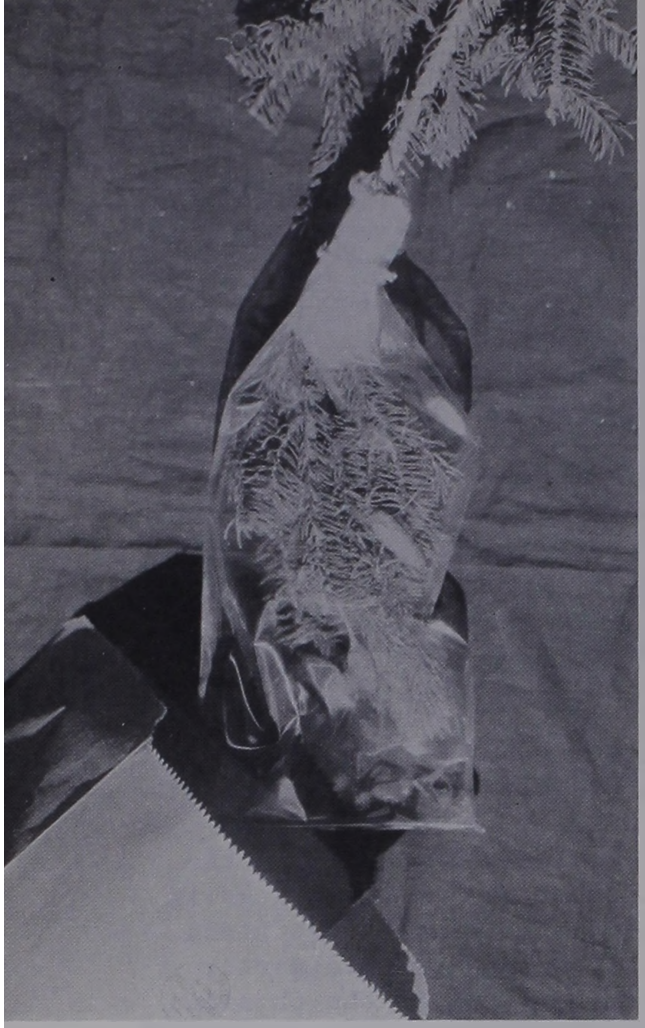
Preliminary measurements of age, height, radial increment, crown size, and bark moisture have failed to reveal any gross differences between attacked trees and adjacent unattacked trees. Studies of larval habits showed that, although quaking aspen is almost exclusively chosen in the field, the larvae survived in bigtooth aspen lumber and in birch logs if the tunnels were kept somewhat moist. When placed in freshly cut birch logs the larvae remained inactive. However, after the logs had partly dried out they resumed normal activity. Continued study of the physical requirements of the borers themselves may answer such questions as: (1) Why are certain trees attacked while adjacent trees remain undamaged? (2) What effects do certain changes in stand conditions (logging, defoliation, disease) have on the borers? (3) Do certain clones or physiological conditions affect the impact of the borers?

Biology of Cone and Seed Insects

Recent surveys show that insects have caused extensive seed destruction in white spruce on the Superior National Forest. With the current interest in the creation of seed orchards, research is essential to find means for protecting cones and seeds. Preliminary studies were begun in 1959 to describe some of the basic biology of the species involved. In many cases the identity of the seed-infesting insect cannot be ascertained without representative specimens from all the life stages. This calls for careful rearing experiments not only to identify the insects but also to provide a correlation between the time of caging, date of attack, and period of activity of a particular species of insect.

Damage Potential of Pulpwood Borers

Past experience has shown that extensive mortality can occur in the spruce-fir type infested by the spruce budworm in northern Minnesota. In anticipation of the extensive salvage operation that may follow, a series of experiments was established in the fall of 1958 to determine whether any particular method of piling pulpwood tends to protect the wood from attack by Monochamus borers. To date it has been learned that exterior logs in a pile are attacked nine times more frequently



Type of cage used to rear white spruce cone and seed insects. (See previous page.)

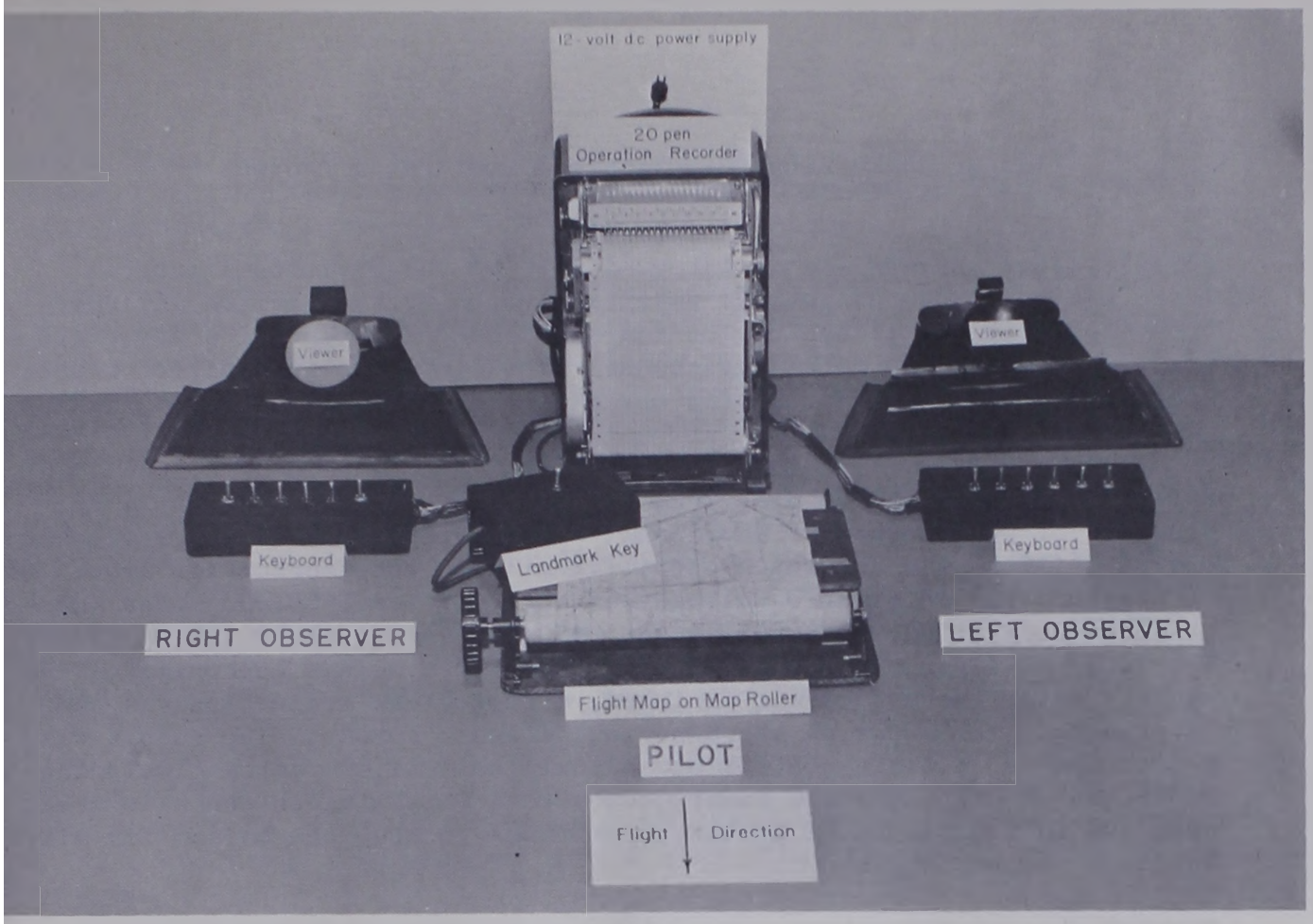
than interior logs. In addition, logs piled in the open were attacked ten times more frequently than those piled in the shade. Further observations in these experiments should reveal the most protective method of piling and the volume of wood loss due to the borers under various piling conditions.

Improvement of Aerial Survey Techniques

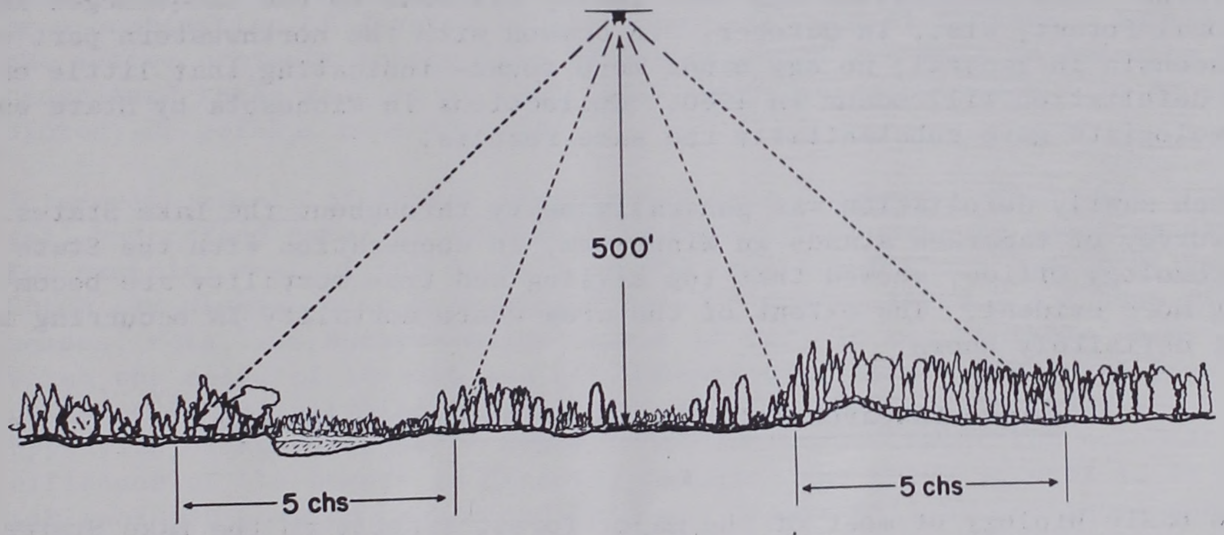
Investigations were undertaken in 1957 to find more efficient aerial methods for detecting and appraising insect defoliation. The current spruce budworm outbreak on the Superior National Forest provided the needed degrees of defoliation. An aerial survey team from the Beltsville, Md., forest insect laboratory, equipped with observation and recording equipment, cooperated with the Station. To augment the ocular observations, a high-speed camera with color film was used to good advantage. Ground checks were made on representative areas in each degree of defoliation to correlate ocular and photo estimates with actual tree conditions. The fieldwork was carried out during June and July of 1957, 1958, and 1959.

The analysis of the field data will be completed in 1960. Research on ocular observations has indicated that on clear days moderate defoliation can be accurately detected at 1,000 feet. If the visibility is poor because of haze, or if the defoliation is light, the optimum height for accurate observation may be as low as 500 feet. Pilots are reluctant to fly lower because of the safety hazard.

Preliminary results indicate that various degrees of defoliation can be accurately appraised from color photographs. This is important as a means of correcting errors in the observers' estimates of defoliation. It may also prove feasible to use this method in lieu of ocular observations for some types of aerial surveys.



SCHEMATIC DRAWING OF SAMPLING STRIPS VIEWED BY TWO AERIAL OBSERVERS



Equipment used in aerial surveys.

Insect Evaluation Surveys Are a Continuing Project

Forest insect surveys are an integral part of the Divisional program. Three general types of surveys were carried on by the Station in 1959: detection, biological evaluation (an appraisal of potential destructiveness), and postspray mortality checks. The first two are Station responsibilities; the last was carried out at the request of the agency making the control operation.

Detection surveys may be made from the air, on the ground, or by a combination of both methods. The annual aerial spruce budworm survey covered over 4 million acres of which about 1.2 million were spruce-fir type. Of the latter, the defoliation categories were: severe, 63,000 acres; moderate to heavy, 560,000 acres; light, 470,000 acres; none, 130,000 acres. The total cost per hundred acres of spruce-fir type was approximately 10 cents. After the survey was finished, a biological evaluation was made on proposed sale areas on the Superior National Forest. The result was a proposal to initiate control on approximately 21,000 acres, including 300 acres of campsites and summer homesites. Spraying on the sale areas would be in the nature of holding operations to keep the balsam fir alive until it can be logged.

Careful checks of Saratoga spittlebug and European pine shoot moth populations in Lower Michigan revealed that inclement weather took a heavy toll of these pests. Only 134 acres of spittlebug-infested red pine required chemical control. However, spring surveys showed that spittlebug populations remained high in northern Wisconsin and about 2,500 acres of red pine plantations required control in 1959.

A forest tent caterpillar egg-band survey was made on the Chequamegon National Forest, Wis., in October. In common with the northwestern part of Wisconsin in general, no egg bands were found--indicating that little or no defoliation will occur in 1960. Collections in Minnesota by State entomologists gave substantially the same results.

Larch sawfly defoliation was generally heavy throughout the Lake States. A survey of tamarack stands in Minnesota, in cooperation with the State Entomology Office, showed that top killing and tree mortality are becoming more evident. The extent of the area where mortality is occurring is not definitely known.

Future Research Will Emphasize Ecological Studies

The basic biology of most of the major forest insects in the Lake States is now adequately understood to allow proper identification of species, prediction of life stage duration, overwintering habits, etc. However, there is still an acute lack of knowledge of the ecology of many of the pests. Until this need is fulfilled, the most efficient means for control

and in some cases the biological advisability of control, cannot be determined. To fill these gaps in our knowledge, emphasis in future research will be directed along the following general lines.

Insect attack in relation to hereditary lines and physiological conditions of the host.--Since the beginnings of forest science, numerous workers have made observations on the resistance or susceptibility of trees to insect attack as influenced by age, environmental conditions, and hereditary constitution of the trees. Everyone is familiar with ideas such as: Vigorous, fast-growing trees are more resistant to insect damage; mixtures of trees by age and species are less likely to sustain insect epidemics; and certain clones or hereditary lines are either more or less susceptible to damage by insects than other lines may be. In spite of the almost ancient origin of these ideas, there have been very few quantitative studies to determine their veracity and the possibilities of economic application. Therefore, there is an urgent need for studies of the effects of soil and other environmental conditions on the insect susceptibility of various tree species--both within the normal range of the species and on the treeless plains. Preliminary plans are already under way for studies of the effect of red pine planting sites on subsequent damage by the European pine shoot moth, species composition of shelterbelts and subsequent insect attack, and stand composition, growth characteristics, and age in relation to aspen stem borers.

Biological and weather factors affecting insect populations.--Population levels (dynamics) of any insect species are primarily affected by parasites, predators, diseases, and weather conditions. A very delicate balance exists between these factors and the endemic population level of a particular pest. A small lessening in the depressive effect of any of these factors may result in a "snowballing" epidemic. Conversely, a catastrophic collapse of an outbreak population can be brought about by any one or a combination of several of these natural control factors. In all of the active projects in the Lake States attempts are made to describe and understand these factors so that future population outbreaks can be predicted, or perhaps even thwarted.

Interrelationship of forest insects and tree diseases.--There are several well understood cases of symbiosis between forest insects and tree diseases. For example, most of the details in the relation between bark beetles and Dutch elm disease have been worked out. However, there are a host of diseases, rots, and decays--major causes of cull in merchantable trees--in which the roles of insects are not understood. Stem borers have been implicated in establishing infection courts for the very destructive Hypoxylon canker disease of aspen. Studies to determine the economic significance of the borers in directly damaging the trees as well as in establishing Hypoxylon canker and rots and decays will be continued and intensified.

Insects affecting cone and seed production.--Seed loss due to insect activity has been an important factor in preventing natural regeneration of

some species. For example, even after heavy seed production by mature white spruce left for seed trees, regeneration has been poor. The development of seed orchards makes seed and cone insects an even more serious problem. Current field and laboratory studies of the life history and habits of these insects should be intensified and expanded so that controls can be developed and an adequate supply of high-quality seed assured both for natural regeneration and for planting.

Development of aerial survey methods for plantation insects.--As the tree crowns in forest plantations close in, ground surveys for insect pests become increasingly difficult and inaccurate. Research on aerial surveys using color photography may lead to inexpensive methods for evaluating infestations of such insects as the white-pine weevil, the pine root collar weevil, the European pine shoot moth, and the pine tortoise scale.

FOREST DISEASES[2/]

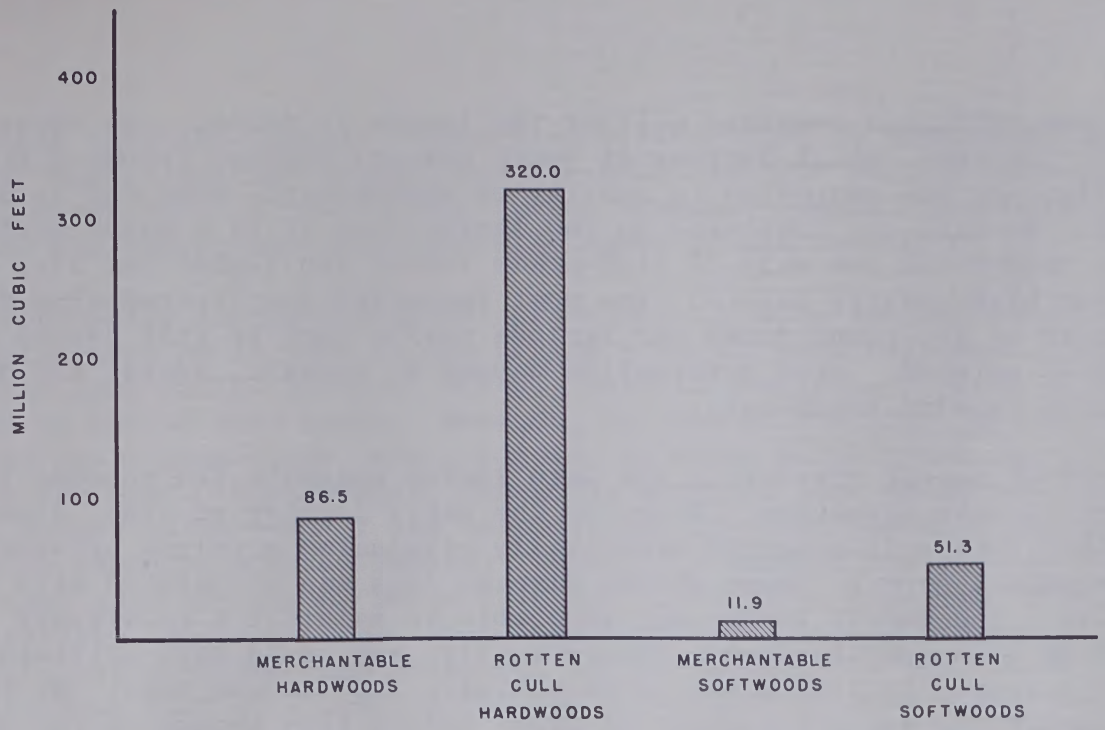
Present Disease Situation--the Result of Past Practices

Current annual timber losses from diseases in the Lake States are nearly 700 million cubic feet or about 2 billion board feet. The seriousness of this loss is best understood when compared with annual net growth: 1.2 billion cubic feet or 2.7 billion board feet. Without losses due to disease, board-foot growth would be nearly 60 percent higher.

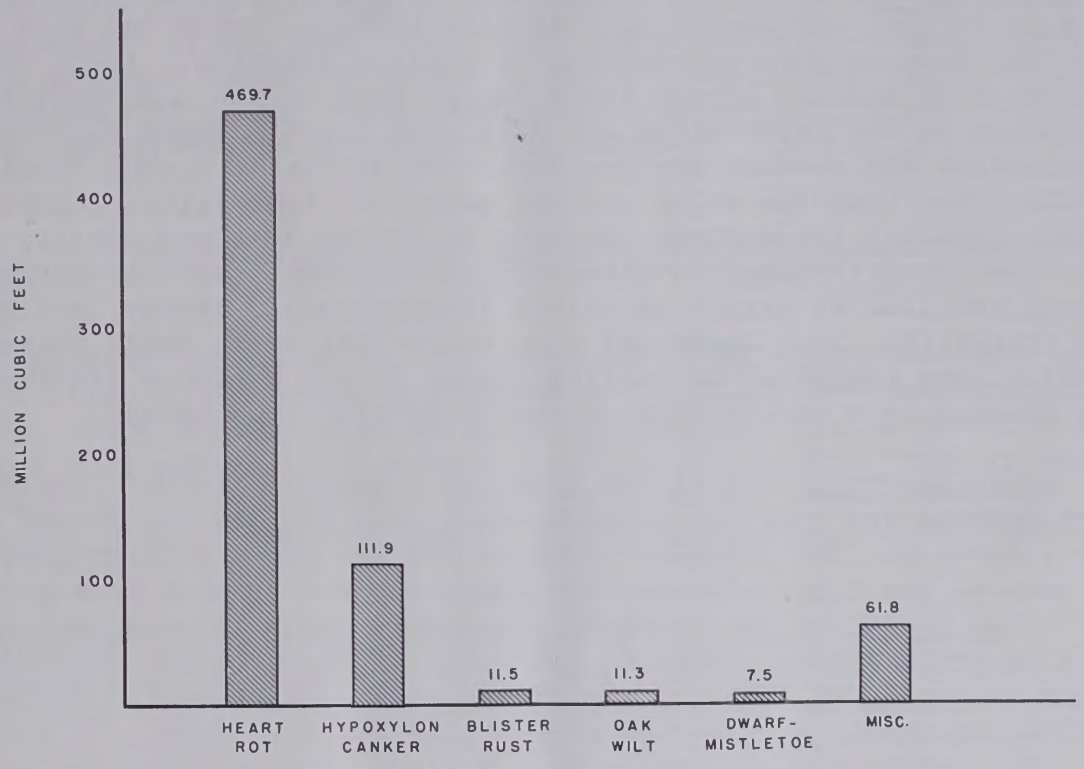
The kinds of diseases primarily responsible are an important consideration. The heart-rot fungi, which as a group attack all tree species, account for about 70 percent of the loss--more than all other diseases combined. Significantly, only about 20 percent of the heart-rot loss is accounted for by cull increment in trees that are still merchantable. The remaining 80 percent, or more than half of the total disease loss, is in rotten cull trees, which occupy growing space that should be devoted to sound trees.

The balance of the loss is due mainly to four virulent diseases. By far the most important of these is Hypoxylon canker of aspen, which causes 16 percent of the total disease impact. The others are white pine blister rust, oak wilt, and dwarfmistletoe on black spruce. There are, of course, several other diseases that are severe in some localities, but they do not contribute appreciably to the losses for the region as a whole.

2/ Forest disease research at the Lake States Forest Experiment Station is set up as a Division program. Dr. Ralph L. Anderson is the Division Chief. His staff at St. Paul includes Dr. Kenneth Kessler, Gerald Anderson, and Darroll Skilling. In addition, Dr. Eugene Van Arsdel is located at the University of Wisconsin, Madison.



The distribution of growth impact caused by heart rots. Note the dominance of rotten cull trees over cull in merchantable trees and how volume losses in hardwoods dominate those in softwoods.



The current growth impact of the most important diseases. Note the overall dominance of heart rots and how Hypoxylon canker dominates the killing diseases.

The above estimates consider neither the losses in forest tree nurseries due to root rots, which destroy at least several hundred thousand trees annually, nor the reduction in quality of merchantable wood due to disease attack. No data are available on the latter, but it is a major problem in the production not only of high-grade veneer and lumber but also of pulp for high-quality papers. The most important quality-reducing diseases appear to be incipient decay and various stains such as that caused by bacterial wetwood. Stem deformation caused by cankers, rusts, and dwarf-mistletoe is also important.

A glance at forest history in the Lake States suggests the reasons for the present disease situation. Prior to the early logging of pine, diseases and other destructive agents essentially eliminated a volume of wood equal to the annual growth. Most of the disease loss was associated with over-maturity. The forest lands thus were able to maintain a relatively large volume of high-quality wood. Theoretically, man could have utilized this virgin resource in such a way as to minimize the disease loss: By the wise harvesting and utilization of trees before they became overmature he could have salvaged an amount equal to the annual growth (possibly thereby increasing the growth) and maintained a high-quality forest. Instead, utilization of the virgin forest increased by severalfold the impact of disease losses on our present forests.

The destructive logging of the virgin pine over most of the forested area, followed by several decades of uncontrolled burning, converted much of the area to tree species more susceptible to serious diseases. About 22 million acres or 40 percent of the total forest area in the Lake States are now dominated by the aspen-birch and jack pine types. These short-lived species decline and develop serious heart-rot losses at a much earlier age and smaller size than the white and red pines of the original forest. This alone accounts for a large increase in volume loss and quality reduction that can be attributed to disease. In addition, aspen is subject throughout its life to severe mortality from Hypoxylon canker; and jack pine is susceptible to a number of stem rusts that cause early mortality, deformation, and reduction in quality. Much of the region's disease-problem complex is a consequence of this extensive type change.

On the remaining 60 percent of the area, the change in forest condition has been gradual and subtile; nevertheless, here too disease losses have greatly increased. The principal reasons are two types of high grading. First, most of the high-value conifer component was removed from mixed stands. This increased the hardwood component, which is much more susceptible to decay losses. Second, over much of the area the sounder, better trees were removed, leaving the rotten culls and potential culls. This means the relative volume of rotten cull has increased. In addition, fire scars, logging wounds, and cutting methods that have favored sprout regeneration have increased decay.

The disease problem has been further altered and intensified by the inadvertent introduction of new diseases through transporting infectious

materials into the region. White pine blister rust is largely responsible for the relegation of what was our most valuable conifer to a relatively minor role in the current forest economy. Dutch elm disease has invaded the region and doubtless will cause severe losses.

The progressive forest management practices and more intensive utilization now being applied to much of the region's forest area can, with time, minimize some of the disease losses. This is particularly true of losses caused by rotten cull trees. However, on some of the area, particularly that in small ownerships, the situation is being perpetuated much as it was in the past. Furthermore, currently accepted good management practices do not solve some of the more serious problems and in some respects actually increase disease impact. There is a popular and widely held concept that good management means a forest of thrifty, vigorous trees and that thrifty, vigorous trees mean less susceptibility to disease. This is certainly true for some diseases, but it is not true for the more important ones such as Hypoxylon canker, white pine blister rust, oak wilt, and dwarfmistletoe. Management practices to an unknown extent increase the disease hazard through creation of unnatural environments, with plantations presenting the extreme example. Even when man is trying to create a better forest and is reducing some forms of disease loss he doubtless unwittingly increases others.

The Nation's rapid increase in population (one rough estimate shows that it may double by the year 2000) will have a great and increasing influence on the economic impact of forest diseases. As the population expands and the standard of living rises, the greatly increased demand for wood will reduce our ability to afford present losses.

Past Research and Experience Can Help Reduce Losses

Starting about 50 years ago, an ever-increasing effort has gone into research aimed at providing the knowledge necessary to reduce tree disease losses. This effort, although small in relation to the problems involved, has produced much basic information and developed some control measures. For example, the extensive application of direct control measures has undoubtedly greatly reduced losses by nursery disease and white pine blister rust.

Indirect control applied by foresters in management practices is often not recognized as disease control. Yet knowledge that the pathological rotation is the longest one that is feasible and the general recognition of this in management plans are slowly but surely causing a major reduction in decay losses. Upgrading stands by partial cuts that remove and utilize the poorer trees has an even greater effect in reducing decay in intensively managed stands.

It is easy to be discouraged by our ignorance about many of the more serious diseases and to assume that the probabilities of developing practical control measures for widespread application are rather remote. This is far from the truth. The knowledge available from past research and experience has provided practical means for eliminating something approaching 50 percent of present losses. To a large extent this can be gradually accomplished by application of two simple rules--stay within the pathological rotations and eliminate rotten cull trees.

Nevertheless, difficult disease problems remain to be solved effectively--primarily those pertaining to the highly virulent diseases. But the situation should not be viewed pessimistically. To a large extent, the present situation with its severe losses is a byproduct of man's past activities. Although some things cannot be undone, it seems reasonable that, with intelligent and concerted effort, most of the problems can be alleviated. This view is encouraged by the major progress made in human and agricultural pathology as a result of intensive effort. Furthermore, the ever-increasing intensity of forest management should make greater control efforts economically feasible.

An Appraisal of the Future Situation Aids Program Direction

As time passes the relative importance of some diseases will doubtless change. An effective research program must be based on the probable future situation, since it takes time to solve the difficult problems involved. In some respects, it is impossible to foresee what the future holds in store; but in others, an educated guess can be made.

Of the five diseases currently causing the most damage, no appreciable change in severity is indicated for Hypoxylon canker of aspen and white pine blister rust except to the extent that improved control measures may be developed and applied. As the old-growth sawtimber resource of the West is depleted, however, the economic impact of blister rust will increase.

As has been pointed out, intensified management and utilization will appreciably reduce rotten cull trees which now account for about half of the total disease loss. To a minor extent this will be offset by some increase in defect in merchantable timber due to such things as wounding of residual trees in selectively cut stands. In the long run heart losses should be greatly reduced. The extent to which they now dominate indicates, however, that they will remain the primary cause of disease losses.

A severalfold increase in oak wilt losses in future decades is likely unless intensive control measures are applied. The impact of this disease on the region as a whole may eventually approach that of Hypoxylon canker. It probably will not equal it despite the much more severe damage per acre affected, because oak occurs as a type on only $6\frac{1}{2}$ million acres while aspen type covers over 18 million acres.

White pine blister rust, one of the most serious foreign diseases that have invaded this region, causes serious mortality of young white pine. (Photo courtesy University of Minnesota.)

Dwarfmistletoe infection is currently limited to a small portion of the black spruce type, largely because of past fires, the natural control for this disease. With the present effective fire control practices, dwarfmistletoe prevalence will probably increase severalfold over a period of many decades unless substitute control measures are employed. Since the area of commercial black spruce type in the region is a little less than 3 million acres, the future volume loss will not approach that for the diseases previously discussed. The high value of black spruce, however, increases the economic significance of dwarfmistletoe.

The above considerations indicate that the relative impact of these diseases will change appreciably but not their order of importance.

Two other factors in the disease situation defy adequate evaluation because we have no basis for determining probabilities. These are new and introduced diseases. Significantly, these unknowns bear on possible increases rather than decreases in future disease impact.

Hard maple mortality caused by maple blight, the most alarming new disease in the region.

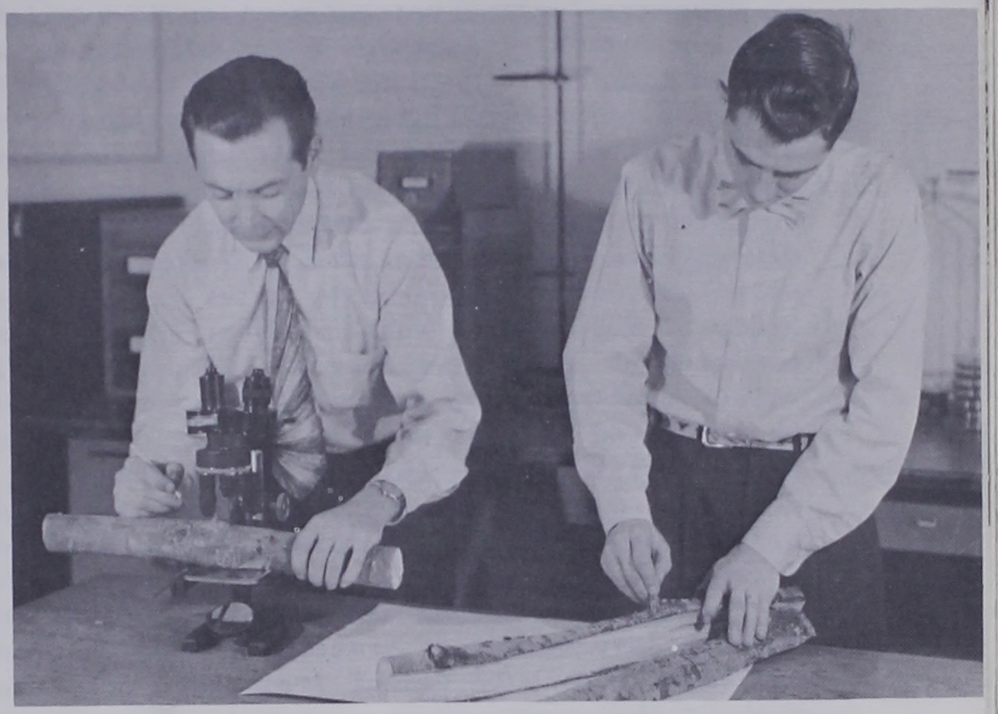
Of the new diseases, the most important appear to be maple blight, maple dieback, and jack pine root rot. There is no sound basis for estimating their potential for spread and intensification because their causes are unknown. Likewise, since they have been present for so few years, no estimate based on empirical experience is adequate. For these reasons, they must be assumed to be major threats for the future until such time as our knowledge about them may prove otherwise. Other relatively new diseases could cause major future losses, but they are not viewed with as much alarm. The most important of these are a canker disease of red pine plantations in the vicinity of Kenton, Mich., nursery root rots affecting black spruce and red pine, a decline of white pines, stalactiform rust of jack pine, and an unexplained oak mortality.

The historical record shows that introduction of diseases foreign to the region is responsible for some of our most serious losses. The record also suggests that further introductions should be anticipated. The recent invasion of the region by Dutch elm disease is a case in point. In addition to possible introduction of presently unknown diseases, a number of diseases now in other areas are recognized as serious potential threats. Among the more important of these are the following: (1) Fomes annosus root rot is now present south and east of this region and regarded as a major threat to intensively managed conifer stands and plantations. The fungus is already present in the region, but no damage has been noted; possibly a virulent strain needs to be introduced before serious damage will occur. (2) The birch dieback that devastated the northeastern States and eastern Canada might enter this region. The cause of this disease is still a question, so there is no basis for even guessing at the probabilities of this happening. (3) Bacterial canker of poplars, a very serious disease in Europe, must be considered potentially dangerous here. (4) Larch canker, also a serious European disease, is a possible threat to tamarack. (5) The beech nectria-scale disease is causing serious local damage in the northeastern States and probably could invade the Lake States.

Fundamental Studies Are Basic to Progress

Four kinds of studies are needed to solve disease problems. These are surveys, fundamental studies, development of control methods, and development of practical techniques for their application.

Surveys are needed (1) to maintain surveillance for new diseases that may appear, (2) to note changes in the distribution and prevalence of diseases that are relatively new to the region, and (3) to appraise as accurately as possible the present and potential impact of specific diseases on forest productivity. The last, appraisal surveys, presents the most difficult and expensive problem. Yet, except for the new diseases that appear, the soundest basis for determining the order of priority for research needs is adequate information on relative impact of the various diseases, plus due consideration of the present status of knowledge.



Hypoxylon cankers on aspen are examined by Dr. Ralph Anderson and Darroll Skilling in an effort to determine the entrance point for the pathogen. This disease is the principal cause of tree mortality in the region.

Fundamental studies are most important and are urgently needed for all diseases. These studies are of three types: First is the determination of the cause of each disease. Second is development of a comprehensive knowledge of the biology of the pathogen, particularly the mode of infection and means of dissemination, plus reactions of the host to attack. Third is the determination of the influence of the various environmental factors on dissemination, infecti . and host reactions. In forest disease control a detailed knowledge of environmental influences is particularly important, because most conceivable indirect control measures involve manipulation of environment. A fourth area needs study if the objective is to develop genetic resistance to disease; then the host-resistance characteristics that vary with genetic constitution must be determined and the genetic characteristics in the pathogen explored.

Weather stations provide information on microclimate as it relates to white pine blister rust. In the station shown data are collected on the influence of an aspen overstory. (See previous page.)

If adequate fundamental information is available, control methods can be developed with maximum speed and efficiency, because intelligent choices can be made as to methods meriting investigation. In the absence of such information, control studies must be pursued on more of a trial-and-error basis. It must be assumed that under such circumstances much of the effort will be less productive. Since economic limitations often preclude the use of expensive direct control measures, emphasis should be on indirect methods involving the influence of site, stand composition, stand structure, and stand density, plus individual tree-risk classification. Study of more direct methods involving eradication of the pathogen or creation of protective barriers is particularly pertinent where high values are involved, such as in nurseries, or where extensive areas can be protected by treatment of localized patches of infection as is true for oak wilt and dwarfmistletoe. A promising new development in direct control techniques is the use of antibiotics such as cycloheximide, which has proven effective for blister rust on western white pine.

Once effective control methods have been discovered, one task remains. That is development of practical techniques for application. The principal task here is to select from among possible alternatives the precise methods that are most consistently effective and the most economical to apply, require the least deviation from prevailing silvicultural and management practices, and can be effectively applied with the least technical know-how. This stage in the solution of a disease problem requires an integrated approach involving close cooperation of pathologists, silviculturists, and management and other forest research specialists. The principal approach used in developing practical application is the pilot-scale control study.

One difficulty in developing an adequate program is the large number of disease problems demanding attention and the relatively small research effort. Solution of these problems will require sustained, intensive research. Consequently, pathologists must either spread themselves very thin and take a rather superficial approach to the problems or else ignore

many of them completely. There are limits to the extent to which problems that are causing serious losses can be ignored. Except for the vast area of heart-rot problems, the more important diseases are receiving at least some attention. Most of them, however, are not receiving the intensive effort that would be most productive. The limited financial resources currently available are responsible for this situation.

Another problem is posed by the need for increased emphasis on fundamental studies. To pursue such studies on the scale desirable would require a major increase in facilities and equipment. These are necessary primarily, of course, to prosecute the work, but also to recruit and hold in the forest disease field men with a high order of scientific ability. A considerable number of highly competent forest pathologists have been lured away to other related fields by better facilities for doing research.

Since most forest disease research is conducted by public agencies, increased effort in the field must be a consequence of public awareness of the need. This need will become increasingly clear as the rapidly expanding population and rising standard of living demand more and more wood from the same or possibly even fewer acres of forest land.

Forest disease research is not likely to be an exception to the historical record of research in general. This shows that in the long run, although much of the effort gives little return, the total return exceeds by severalfold the total effort made.

Practical Results Have Been Obtained on Some Diseases

Federal research in forest diseases in the Lake States began in a small way about 10 years ago. Since then several modest increases in funds have permitted a gradual expansion in personnel and in the research program. The following pages describe briefly progress in research, which has been confined to the more important diseases.

Diseases of Conifers in Natural Stands

Three diseases are causing major losses in natural conifer stands: Heart rots, white pine blister rust, and dwarfmistletoe on black spruce.

Among the conifers, hemlock and balsam fir are the most susceptible to severe heart-rot losses. Past work and experience have provided reasonably sound pathological rotations for the commercially important species. In the Lake States region no intensive study of conifer heart rots is under way at present. Studies should be made for all species, especially balsam fir, to develop more information on individual tree-risk classification, site relations, and the influence of various stand management practices on heart-rot development. Although more research effort has been devoted to heart rot of balsam fir than to that of other species, the high susceptibility of balsam fir and the large forest area that is

Heart rot of balsam fir, caused by Stereum sanguinolentum. This is the most important conifer decay problem in the Lake States.

converting to it by natural succession indicate that heart rot in this species is a long-term major problem for the region.

Past research on white pine blister rust has provided a greater store of fundamental information than is available for most diseases. As a consequence, the control method based on Ribes eradication was developed and has now been applied to extensive areas. These past studies have also indicated a number of promising leads for other investigations that should provide the means for more effective reduction of the disease's impact. Four important studies are now under way in this region.

One of these, conducted in cooperation with the University of Wisconsin, concerns the influence of microclimate on the prevalence and distribution of infection. Topography and stand characteristics have significant influences on the microclimate. Thus high- and low-risk areas can be identified, and in the southern part of the region a considerable savings in control costs has already been achieved by eliminating Ribes eradication on low-hazard sites. The study also covers the problem in some northern areas of exceptionally favorable microclimate for rust that permits long-distance dissemination of the disease to pine. Detailed knowledge of microclimatic influences will permit more effective and economical control of the disease.

The Station is cooperating with Blister Rust Control personnel in developing methods for application of antibiotics to eastern white pine. It is believed that with some modification the treatment methods developed for rust on western white pine can be adapted to eastern white pine.

Technique for studying long-distance dissemination of white pine blister rust in problem areas. Top, captive balloon used to obtain temperature profiles, and colored smoke released to trace air currents. Bottom, smoke movement influenced by a temperature inversion layer; spore dissemination would follow the same path as the smoke.

A third study, in cooperation with the University of Wisconsin, involves field-testing promising selections of white pine for rust resistance. These selections have been provided by the University's program to develop white pine that have genetic resistance to the rust.

In cooperation with the University of Minnesota, the Station is engaged in a study of the genetics of the blister rust fungus. This study has demonstrated that the rust does vary genetically, but limited efforts have not as yet found evidence of variability in pathogenicity on the pine host. It is important to determine whether such variability exists because of its bearing on breeding trees resistant to the disease.

The most important needs in blister rust research will be met by continuing and increasing efforts on work currently under way.

Although further fundamental studies of the dwarfmistletoe problem are needed, particularly on such problems as the means of long-distance dissemination, some control recommendations have been provided by a study

conducted by the University of Minnesota in 1947-48, the results obtained in the western States on other dwarfmistletoes, and a very limited amount of attention by the Station. The status of knowledge has reached the point where pilot-scale control studies should be initiated.

The above conifer diseases account for most of the current disease impact. However, some other diseases are important because of severe localized damage or unknown potential for intensification. The status of these is as follows:

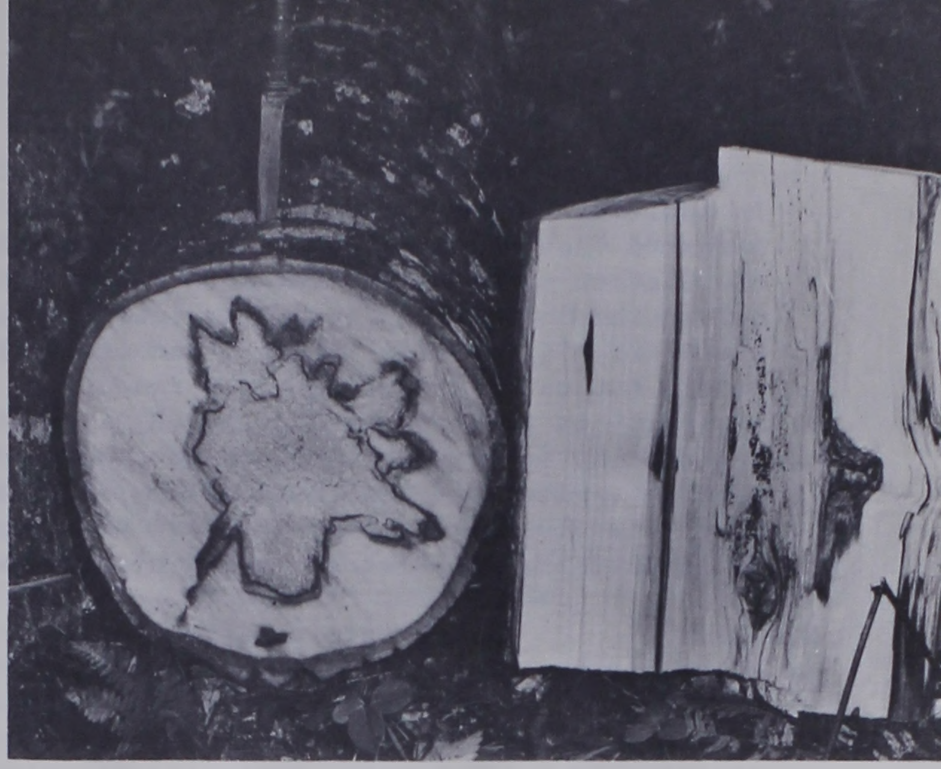
1. Four stem rusts on jack pine are causing considerable damage. A preliminary study of the jack pine-sweetfern rust conducted in cooperation with the University of Minnesota has revealed that the disease is very prevalent in some stands, particularly plantations. The cankers caused by the disease not only cause serious stem deformation but also permit early establishment of heart rot. During this study it was found that Comandra rust is more common on jack pine than had been previously supposed. Stalactiform rust, not previously known to be present in the Lake States, was also found at a number of locations. The fourth rust, pine-oak gall rust, is being studied by the University of Wisconsin. All of these rusts need intensive research to provide a foundation of fundamental information similar to that available for white pine blister rust. None of the Station staff is currently working on this problem.

2. The decline and eventual death of scattered white pine throughout the region has been noted for some time. So far no research attention has been given to the problem, but an effort should be made to determine the cause.

Diseases of Hardwoods — The three diseases causing major losses in hardwood stands are heart rots, Hypoxylon canker, and oak wilt.

In the past some studies have been made of the heart-rot problem in northern hardwoods, aspen, and oak, including a study by the Station of decay development in logging wounds on hard maple. This work was done in cooperation with the Michigan College of Mining and Technology and the University of Michigan. The data obtained have provided a reasonably sound basis for pathological rotations and fair information on cull detection in standing trees. Very little attention is currently being given to hardwood decay problems because of the urgent need for work on diseases causing mortality. All of the hardwood species need intensive study to provide adequate information on site relations, influence of various management practices, and individual tree-risk determination.

For several years the Station has been cooperating with industry on the problem of Hypoxylon canker on aspen. Most of the effort has been directed at determining the relationships between prevalence of the disease and various stand and site characteristics. A number of universities have also been giving the problem some attention. The Station is now analyzing



Heart rot in aspen, caused by Fomes igniarius. This fungus attacks many hardwood species and is responsible for more rotten cull than is any other heart-rot fungus.

the data accumulated so far, but results to date have been very limited. A major reason is lack of fundamental information, particularly on the mode of infection, a problem which has proven difficult to solve. The seriousness of the disease justifies continued intensive effort.

The oak wilt problem is already being studied intensively at many universities and at other forest experiment stations. For this reason the Station has not initiated any research on it, but we are conducting surveys to determine the rate of spread of the disease. These indicate a slow and steady increase in severity. Continuation of the present studies should prove reasonably adequate.

Maple blight, which appeared in northeastern Wisconsin in 1957 and caused severe local damage, is the most alarming disease currently in the region for several reasons: Hard maple is one of our most valuable species, the disease destroys trees of all size and vigor classes, and its potential for spread and intensification is unknown. The disease caused little additional damage in 1958 and 1959, but it is still too early to be certain about its future course. The problem is receiving major research attention. The Station, industry, and the University of Wisconsin are cooperating on investigations of the pathogenic, environmental, and insect aspects of the problem. So far the exact cause has not been found. It appears to be a complex, with insect defoliation a major factor. The Station plans to increase its effort on the problem next year.

During the past few years excessive dieback of hard maple has been noted in many areas throughout the region, but it is particularly alarming in the western part of the Upper Peninsula of Michigan. Symptoms are quite similar to maple blight except that dieback is limited to the older overstory trees and progresses more slowly. The University of Wisconsin has given some attention to a similar problem in central Wisconsin. The Station plans to initiate a study of this disease.

In addition to the above three, there are a considerable number of lesser hardwood diseases that are currently receiving little or no attention. The Station has no plans for study of these problems in the near future, but in the long-term picture they merit attention. The more important of these are: (1) Stains in aspen and northern hardwoods that do not reduce volume but cause serious quality reduction, (2) an unknown cause of oak mortality in northern Wisconsin, (3) a number of canker diseases affecting quality of several hardwood species, and (4) diebacks and wilts affecting various species, especially yellow birch, ash, and elm. Although Dutch elm disease is a major threat to the region, the Station does not anticipate any immediate research program on it.

Diseases in Plantations

Experience elsewhere indicates that disease problems in the region's plantations will become more severe as the trees grow older. At present two diseases appear to be largely unique to plantation situations. What seems to be a root rot is causing essentially a 100-percent mortality of pole-size jack pine in patches scattered through old-field plantings in central Wisconsin. Whether this situation will become more widespread is unknown.

During the past decade a disease showing a variety of symptoms has destroyed several thousand acres of red pine plantations on the Ottawa National Forest in Michigan. The most consistent symptom is the presence of numerous cankers on the affected trees. Although Station personnel in both pathology and timber management have given the problem some attention, it is still unsolved. It merits intensive study.

Although not known to be causing damage in this region, Fomes annosus root rot is the most serious potential threat to our plantations. Careful surveillance should be maintained for its appearance.

In addition to the problems in commercial forest plantations, the diseases of trees planted in shelterbelts on the Northern Great Plains represent a major portion of the Station's responsibility for disease research in that region. Shelterbelt insect and disease problems are now being analyzed. Heart rot, canker and dieback of Russian olive, and boxelder blight are causing considerable concern, as are to a lesser extent diebacks and blights of other species. To date no work has been done on these diseases in shelterbelts, although some attention is being given to the boxelder blight in nurseries. The Station plans to initiate research on these problems.

Diseases in Nurseries

The most serious disease problem in Lake States nurseries is root rot. Past research has provided an effective control for a root rot of white pine seedlings and transplants in the U. S. Forest Service nursery at Wellston, Mich. Some progress has also been made in determining the probable cause of the disease. Similar root rots of black spruce and red pine have recently appeared in other nurseries and are causing very severe losses. Control methods are being tested by the Station and industry to determine whether those developed

for the white pine root rot will be effective. Efforts to find the specific cause of these root rots should be intensified, and testing of chemicals should be continued. Although an effective control of the white pine root rot has been developed that may also work for the others, costs are high and cheaper methods should be provided. Since new nursery problems of this type will probably continue to appear, a sustained research program is essential.

Disease problems are equally as important in Northern Great Plains nurseries, where much of the stock of hardwood species is produced. At present boxelder blight is causing considerable damage. The Station has a study under way to ascertain whether weed killers such as 2,4-D are responsible; so far the best evidence suggests that they may be.

An Overall View

In summary, studies of white pine blister rust, dwarfmistletoe, heart rot in hardwoods, oak wilt, and nursery root rots have produced practical results. Not so encouraging are the accomplishments to date on Hypoxylon canker of aspen, but studies on this important disease must be continued. A number of the current studies such as those on maple blight are still too new to assess results.

Diseases on which the Station plans to initiate work soon are maple dieback and one or two of the more urgent disease problems in the Northern Great Plains area. Most of the current studies need to be intensified and, as soon as funds warrant, new studies will be established, particularly on the heart-rot problems and also on stem rusts of jack pine and the disease presently killing large areas of red pine plantations in Upper Michigan.

F O R E S T F I R E[3/]

Lake States Forests--A Product of Fire History

Fire had played a leading role in developing the land cover types that greeted the first white settlers coming to the Lake States region. From the prairies of the southern and western edges to the expanses of even-aged conifer stands of the northern boundaries, the influences of fire were everywhere.

Early Settlers Lived With the Effects of Fire

Reports from early geological and natural history surveys describe the diverse effects of prehistoric fires on the soils of the region. These accounts attributed the color and texture of the prairie soils to the annual fires of past centuries. They also cited the thinness or nonexistence of organic soil over large portions of the Laurentian Shield as a direct effect of periodic severe fires mentioned by early explorers and fur traders in their travel journals.

In the drier southern parts of the region annual fires contributed to the maintenance of grass as the predominant cover on all but the moister and more sheltered sites along rivers and isolated slopes. Where climate precluded a rigorous schedule of annual burning, as throughout the northern lake areas, fire also left its imprint on the cover types which evolved. The chief characteristics of this portion were the even-aged stands of upland and swamp conifers resulting often from patchy coverage of forest conflagrations at irregular periods of time.

With the coming of white settlers to the region, fire assumed a more dynamic role. Probably no region in the United States shows the effects of wildfire upon its economy to as great an extent as does the Lake States. Fires universally followed the cutting of the magnificent pine and hardwood forests in Michigan, Minnesota, and Wisconsin. It is estimated that nearly 7 million acres of natural pine growing sites were invaded by aspen or by low-grade species as a result of fires that followed the harvest cutting near the turn of the century.

Scores of fires from 2,000 to 20,000 acres in size kept the average annual burn close to 1 million acres over the three Lake States well into the 1930's. Periodically, numerous fires merged to breed the conflagrations for which the area is famous. Nine of the more disastrous fires burned

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3/ Fire research is a part of the program of the Division of Forest Management. R. D. McCulley is in charge of this Division. For the past 4 years Loyd LaMois has been conducting our fire research. In December he was transferred to the Forest Service Washington office, and this position is now vacant.

Logging followed by fire was common in the past.

over a total of 5 million acres and resulted in the loss of 2,500 lives. They are:

Fire	Date	State	Acres burned
Peshtigo	1871	Wisconsin	1,280,000
Michigan	1871	Michigan	2,000,000
Thumb	1881	Michigan	1,000,000
Comstock	1891	Wisconsin	64,000
Phillips	1894	Wisconsin	100,000
Hinckley	1894	Minnesota	160,000
Chisholm	1908	Minnesota	20,000
Baudette	1910	Minnesota	300,000
Cloquet	1918	Minnesota	250,000

Other regions have had their great fires, but none has suffered more often or more severely over the years than the Lake States.

Organization for Fire Control Has Accomplished Much in the Lake States

During the past 30 years the fire picture has changed radically. Dating from the late 1800's forest protection legislation gradually found its way into the law books of the three Lake States. By the end of the first decade in the 1900's all three States had provided for some rudimentary sort of organized protection against forest fires. It was not until 1920 or after, however, that the State control organizations were fully established in essentially their present-day form. Since that time, Michigan, Minnesota, and Wisconsin have progressed steadily in building and financing effective fire-control programs.

The three-State area is now noted for the excellence of fire protection

given their second-growth forests. All forest land in Michigan, Minnesota, and Wisconsin which under present standards is classed as needing protection (this includes nearly all forest land) is under some form of organized protection as compared with the national average of 93.2 percent. Only one-half as many fires in the three States grow into the Class C or larger (over 10 acres) category as do fires over the rest of the Nation.

This record reflects the full maturing of the State fire control organizations and the lessening of fire risk resulting from more effective prevention efforts on a nationwide scale. But it also points up a change in overall fire control needs. Particularly in the Lake States, fire protection has come about as far as is practicable under present-day understanding and methods.

We Remain on the Defensive With Respect to Fire

Michigan, Wisconsin, and Minnesota spend over 4 million dollars annually in protecting their forests from fire. In spite of forestwide protection (geared to a level of effort well above the average for the United States) the three States have an annual fire load of more than 3,000 fires which burn from 20,000 to 100,000 acres.

A recent fire out of control in northern Minnesota.
(Photo courtesy Keep Minnesota Green.)

Weather as related to fuel moisture, fire occurrence, and rate of fire spread was studied in the past.

Hot fires and repeated burns are responsible for a continued growth deficit on much of the forest land now classed as poorly stocked in the Lake States. Fire in the region also accounts for much replacing of valuable species by inferior ones.

Because of rapidly increasing forest values in the region, the fire control picture must continue to improve. New and higher standards of achievement must be the goal for adequate protection in the future.

Research Has Contributed to Good Fire Control Practice

Research and development played a vital part in the building of modern fire control systems throughout the United States. Work done at the Lake States Station contributed much to the measure of success attained in this region.

Since its establishment in 1923 the Station has supported a fire research project. During a period of growth and development the control agencies felt that their greatest need was for research leading to information directly applicable to their immediate problems of organization, planning, and fire control methods. Early emphasis, therefore, was given to thorough problem analyses of each of the three States.

Early fire research also focused much attention on Lake States weather, the analysis of which has proved invaluable as an aid in planning protection efforts throughout the region. Studies of weather and fire occurrence data, along with investigations into fuel moisture and rate-of-fire spread, led to the development of the Lake States burning index meter. The meter remains a basic tool in the day-to-day administration of fire control in all three States.

Fuel classification schemes and dispatching guides have served the State and Federal control agencies in this region over the years. Study of the effects of fire on jack pine mortality in the Lake States is recognized as a pioneering effort in objective analysis of fire effects. Fire damage tables developed at the Station are being used as a guide in estimating damage to timber values throughout the region.

Pioneer work was done in measuring the effectiveness of water and chemical retardants in fire control. Testing and measuring the output of newly developed equipment formed a regular part of the fire research program in the Lake States during the past. Strong cooperation between the control agencies and the Lake States Station was an important feature of this effort.

The Station worked closely with the State control agencies in designing a system of fire record-keeping on machine punchcards. This represented a milepost on the road to effective utilization of fire data in the evaluating and planning processes for fire control management.

Changing Forest Conditions Bring New Fire Problems

Increased Recreational Use Means Greater Fire Risk

Protection needs, like other phases of forest management, respond to changing forest conditions and forest use. A primary factor is the ever-increasing pressures of population throughout the United States.

The Lake States forests are heavily used for recreation, partly because of the many lakes in close proximity to the great population centers of the Midwest. In addition, the area boasts an abundance and variety of wild game which draw large numbers of hunters annually. Without question the future level of recreational use in forested areas will go up, bringing about new dimensions to problems of fire occurrence.

Cutting Practices Affect Fuel Hazards

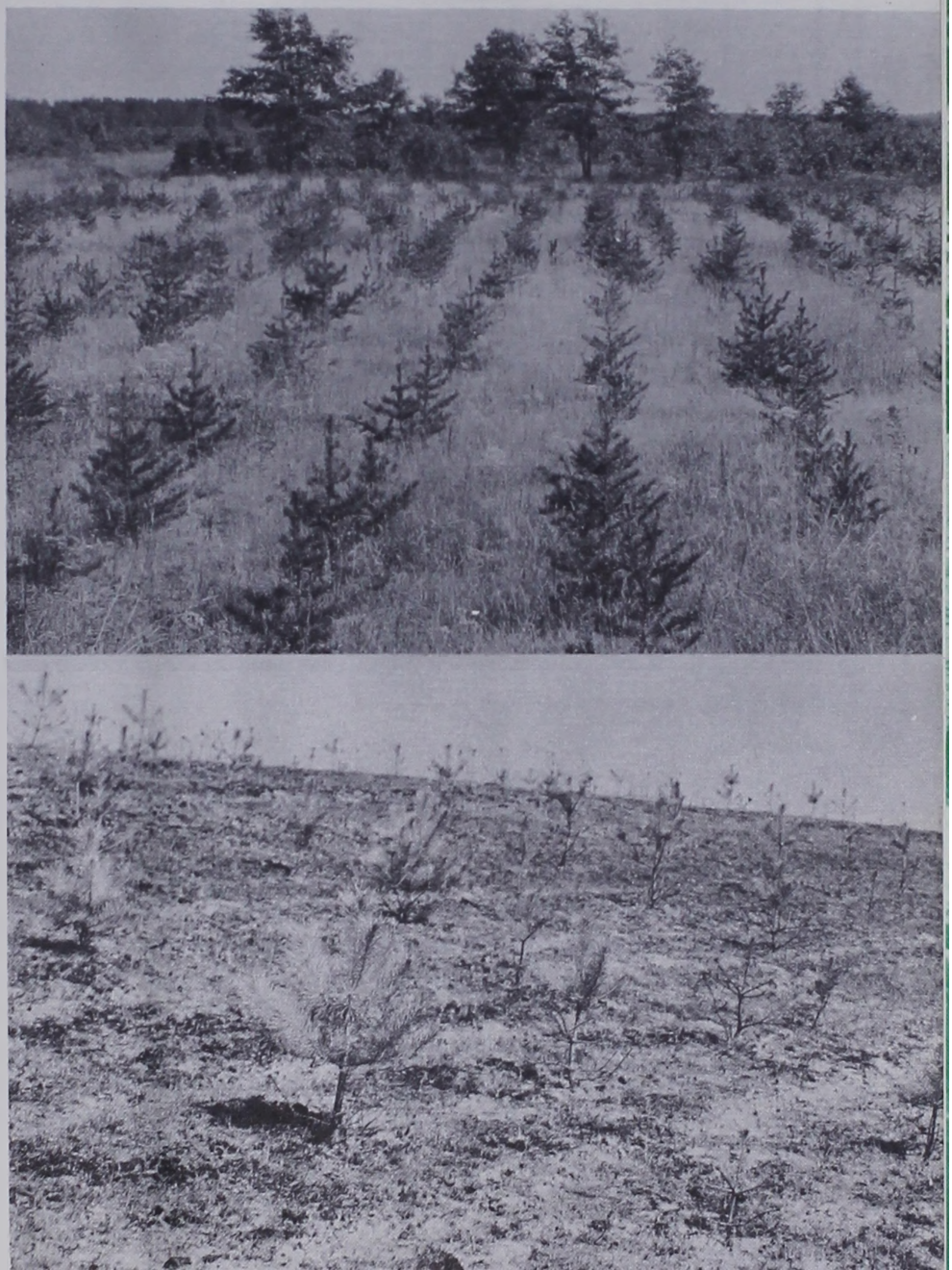
Population increases also result in a rising demand on timber resources of the forest areas. Increased cutting of forest products will, by the last quarter of this century, begin to approach the volume of timber cut during the logging of the region's virgin forest. Hazardous slash accumulations will once again plague fire control forces. Microclimate changes will increase forest flammability in logged-over areas.

Moreover, experiences of the earlier logging era will serve as poor guides for solving future fire protection problems linked to logging activities. Logging operations are now smaller and more widely scattered, in contrast to previous concentrations of larger operations. Harvesting methods and logging equipment have changed radically from the earlier days of lumber production in Minnesota, Michigan, and Wisconsin. New species are being cut and different utilization standards are being used--all of which affect fuels, microclimate, and fire hazard in the future.

The Character of Forest Fuels Is Changing

The Lake States forest is a young forest in which widespread changes in species composition are taking place. Projections to 1975 show a buildup of timber volumes amounting to an increase of 40 percent over the present volume. As more of the poorly stocked and nonstocked areas are rehabilitated and brought into normal production, future timber volumes will eventually approach those that fed the conflagrations of early Lake States history.

Conversion of fuel types through planting also is having a significant impact on the type of forest we can anticipate protecting. The 1½ million acres of established plantations in the Lake States are being added to at the rate of 100,000 acres per year. About 8 million acres are classed as "plantable" by the Forest Survey. Current trends indicate that the present rate of planting is likely to increase, thus adding to the highly hazardous pine area which is associated with most of the region's larger fires.



Pine plantations are especially susceptible to fire damage, as illustrated in the lower picture.

Rising Forest Land Values Call for Better Control

Not only do new uses of forest land directly affect the fire control picture, but they also indirectly bear upon fire control needs through the changes in values of forested areas. These values have climbed steadily upward, and will continue to do so in the future as the demands upon forest resources by a growing population increase.

The fire at Badoura, Minn., and the one at Webster, Wis., both of which occurred on May 1 of this year, serve to illustrate this point. The Badoura fire burned over nearly 15,000 acres including several thousand acres of well-stocked jack pine stands. The Webster fire burned more than 17,000 acres, much of which was young jack pine in plantations and in natural stands. Fires of this size occurring 30 years ago would hardly have been worthy of special note. Today they spell major loss to a more tightly knit and growing forest economy.

Jack pine stands like this one were casualties of the Badoura, Minn., fire in May 1959.

The annual burned area in Michigan, Minnesota, and Wisconsin has trended upward since 1950. Future increases in fire risk and fuel hazards can only result in the magnification of the fire control problem in the Lake States. Increasing values of forest resources make it imperative that this trend be reversed, and that new lower levels of loss to fire be realized.

New Problems Require Intensive Studies

Because many aspects of forest fire management have received but little attention in the Lake States region, the fire research job to be done remains large. The objectives in bettering our regional fire protection performance should be:

1. To assure fire control that meets future standards of protection adequacy.

2. To attain consistent results--at no sacrifice of overall economy during the easy years or dependability during bad years.

3. To stay within the bounds of reasonable costs in providing dependable protection from fire.

A vigorous program of fire research will contribute much toward strengthening our present situation with regard to these goals. It must aim at both broadening the approach and strengthening the effort within several areas of vital importance to fire control agencies in our region.

Of immediate concern in the Lake States region are those phases of fire research which deal directly with problems of fuel hazard reduction and fire detection and suppression techniques. It is within these broad areas of fire control methods that changing conditions over the past years have brought about a real need for intensifying research effort in the Lake States region.

Presuppression Effort Is First Line of Defense

The special problem in fire control attached to expansion of planted acreage naturally suggests the possible use of firebreaks developed as part of the planting pattern. Research is needed to bring about the best and most efficient use of firebreaks in our protection program.

Preliminary trials of chemical herbicide and soil sterilants have indicated that soil sterilants offer some potential in maintaining firebreaks in a fireproof condition. The Station has now initiated a cooperative study with the Minnesota Division of Forestry aimed at evaluating the costs of chemical maintenance over longer periods of time. This study, on State land near Hill City, Minn., also includes evaluation of the less expensive herbicide treatments repeated at more frequent intervals.

Future studies are needed to isolate and define all the various factors bearing on the proper location and design of firebreaks in forested areas. Green vegetative firebreaks may also have practical possibilities in this region.

In the light of what is now known about fire starts and fire spread in the Lake States, there is much we should explore in the way of fuel manipulation to minimize total fire danger. Past studies at the Station have

Wide firebreaks may be effective in fire control.

dealt specifically with slash disposal methods. Needed at the present are broader investigations into problems of silvicultural and harvest treatment of forest stands and their influences upon fire fuels and microclimate. Treatment of all classes of forest fuels by chemical, mechanical, and fire methods should be studied.

Air Detection of Fire May Be More Effective

The use of aircraft in locating new fire starts is rapidly bridging the gaps between modern detection needs and the inadequacies of manned lookout tower systems. Research is needed to evaluate the effectiveness of air patrolling and to establish scheduling and routing of air flights so that tower detection can be supplemented most efficiently.

Suppression Methods Are Improved Through Research

The recent use of aircraft in direct attack upon fire and the development of fire retardant chemicals suggest additional lines of research in the Lake States region. During the summer of 1959 the Station cooperated with the Superior National Forest in evaluating the ground patterns of water cascaded from a Beaver airplane. Results indicated the need for revising the release mechanism to attain full coverage potential of 125-gallon drops. The 3-day tests also showed that using "wetting agents" in the water may reduce somewhat the amount of water reaching the ground. The amount is considerably affected, however, by the relative humidity of the air. Wind velocity, on the other hand,

had no measurable effect (other than in pattern displacement) during these trials.

Tests of airplane equipment should continue with emphasis shifting to evaluating effectiveness of air attack in common tactical situations in the Lake States.

The Station cooperated with the Chippewa National Forest in conducting exploratory trials of borate retardant in ground applications. The trials, conducted on a sedge marsh, strongly indicated that real possibilities exist for advantageous use of retardant chemicals where use of conventional plow equipment is prohibited by terrain features. Further research should aim at establishing a schedule of barrier widths and application rates needed for effective use in a variety of Lake States fuels.

Cascading of water and retardants from aircraft should be explored further in the Lake States. (Photo courtesy Frank Irving, University of Minnesota.)

Fundamentals of Forest Fire Conditions Are Important

Concentration of available research effort on meeting the immediate needs of growing and developing control agencies must not result in the continued neglect of the many fundamental aspects of fire and forest relationships. We are now faced with an almost total lack of basic knowledge, an understanding of which will establish principles for sound practice of fire control and effective use of fire.

Intensive research is needed to develop this basic information. But this flow of new knowledge will demand increased effort aimed at adapting and applying new concepts and measurements to northern forest conditions. We in the North have fire control problems unique to our forest types and economy.

Fuels Are Basic to Fire Behavior

The full destructive potential of a forest fire depends upon the amount of heat energy available for release. The amount of energy and the rate of its release is in turn dependent upon the quantity, character, and arrangement of the fire fuels at the burning site. Means must be developed by which fuel beds may be classified and calibrated in terms that have bearing on fire suppression techniques. The many and varied cover types in the Lake States present a unique problem in gearing fire suppression methods to existing fuel conditions.

Results of a study of fire fuels in red pine plantations in the Lake States revealed influences of spacing, age, and site quality upon the quantities of dead material available as fuel. Future studies should broaden this approach to include other species in natural or planted stands and also to investigate other possible factors influencing fuel quantities.

At present a preliminary study of the moisture content of red pine foliage is being carried on; seasonal trends and variations resulting from atmospheric conditions and soil moisture are being examined. Early data point to possible influences of temperature and relative humidity expressed in terms of vapor pressure deficits.

The possible role of crude fat content in the flammability of pine foliage should also be investigated. We anticipate that indices of flammability will be developed, around which we will be able to design studies on the qualitative aspects of fuels.

Effects of Fire Need Research

The intensity and direction of forest protection efforts depend upon the kinds, extent, and degree of damage anticipated under current conditions. The changing patterns of forest use demand a new array of fire damage factors. The effects of fire upon wildlife, watershed, and recreational values are of vital concern to fire control organizations looking into the future.

Accurate and detailed knowledge of vegetative response to fire is important to wise rehabilitation planning as well as to precise appraisal of forest damage.

At the present time the Lake States Station is maintaining formal studies dealing with the effects of fire treatment upon silvical aspects of forest land management. This work will contribute much needed insight into the effects of fire and their possible impact upon rehabilitation problems and damage appraisal.

Chemical retardants may be useful where fireplows cannot work. Top, a fireline is laid; middle, the fire burns toward it; bottom, the fire is stopped at the line.

In Summary

The forest fire problem in the Lake States has been large in the past. As recently as 30 years ago it seemed almost insurmountable. With inspired effort on the part of the control agencies and with aid from research information, tremendous progress has been made.

The threat from forest fires in the Lake States has been reduced to manageable proportions in the light of today's performance standards; but changing forest conditions continue to bring constant pressure for higher standards of achievement to meet more exacting protection needs of a growing and maturing forest economy.

Fire research in the Lake States continues to work on today's problems--but at a minimum level of maintenance. So that we may cope with tomorrow's needs, fire research in the Lake States must grow in breadth and intensity. Only through an expanded program can fire research contribute its full measure to the task of protecting our region's forest resources from the crippling effects of wildfire.

SELECTED LIST OF STATION PUBLICATIONS ON FOREST PROTECTION

Insects

ANDERSON, ROGER F.

1944. The relation between host condition and attacks by the bronzed birch borer. Jour. Econ. Ent. 37: 588-596, illus.

1947. The Saratoga spittlebug. Jour. Econ. Ent. 40: 695-701, illus.

BATZER, HAROLD O., and BENJAMIN, DANIEL M.

* 1954. Cold temperature tolerance of the European pine shoot moth in Lower Michigan. Jour. Econ. Ent. 47: 801-803.

and WATERS, WILLIAM E.

* 1956. Forest tent caterpillar. U. S. Forest. Serv. Forest Pest Leaflet 9, 4 pp., illus.

BEAN, J. L.

1957. Spruce budworm is a killer. Conserv. Volunteer 20(116): 34-38, illus.

* 1958. The use of larvaevorid maggot drop in measuring trends in spruce budworm populations. Ann. Ent. Soc. Amer. 51: 400-403, illus.

* 1959. Frass size as an indicator of spruce budworm larval instars. Ent. Soc. Amer. Ann. 52: 605-608, illus.

and BATZER, H. O.

* 1956. A spruce budworm risk-rating for the spruce-fir types in the Lake States. Lake States Forest Expt. Sta. Tech. Note 453, 2 pp. (Processed.)

BENJAMIN, D. M.

* 1954. The jack-pine budworm in Michigan, 1953. Lake States Forest Expt. Sta. Tech. Note 414, 1 p. (Processed.)

* 1955. The biology and ecology of the re headed pine sawfly. U. S. Dept. Agr. Tech. Bull. 1118, 57 pp., illus.

and DROOZ, A. T.

* 1954. Parasites affecting the jack-pine budworm in Michigan. Jour. Econ. Ent. 47: 588-591.

DROOZ, ARNOLD T.

* 1956. The larch sawfly. U. S. Forest Serv. Forest Pest Leaflet 8, 4 pp illus.

1960. The larch sawfly, its biology and control. U. S. Dept. Agr. Tech. Bull. (IN PRESS.)

EATON, CHARLES B.

* 1955. The Saratoga spittlebug. U. S. Forest Serv. Forest Pest Leaflet 4 pp., illus.

EWAN, HERBERT G.

* 1957. Jack-pine sawfly. U. S. Forest Serv. Forest Pest Leaflet 17, 4 p illus.

* 1958. The use of the host size and dens factor in appraising the damage p tential of a plantation insect. Tenth Internatl. Cong. Ent. Proc. 363-367, illus.

HODSON, A. C., and ZEHNGRAFF, P. J.

1946. Budworm control in jack pine by f est management. Jour. Forestry 4 198-200.

JAYNES, H. A., and MacALONEY, H. J.

* 1958. The white-pine weevil. U. S. For Serv. Forest Pest Leaflet 21, 7 p illus.

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* Copies available from Director, Lake States Forest Experiment Station, St. Paul Campus, University of Minnesota, St. Paul 1, Minn.

acALONEY, H. J.
1944. Relation of root condition, weather, and insects to the management of jack pine. Jour. Forestry 42: 124-129, illus.

_____ 1957. The red-headed pine sawfly. U. S. Forest Serv. Forest Pest Leaflet 14, 4 pp., illus.

_____ and DROOZ, A. T.
1956. The jack-pine budworm. U. S. Forest Serv. Forest Pest Leaflet 7, 4 pp., illus.

ILLER, W. E.
1958. Control of the European pine shoot moth with concentrated sprays. Lake States Forest Expt. Sta. Tech. Note 543, 2 pp., illus. (Processed.)

_____ 1959. Preliminary study of European pine shoot moth parasitism in Lower Michigan. Jour. Econ. Ent. 52: 768-769, illus.

_____ and HAYNES, D. L.
1958. Timing DDT sprays in the spring for European pine shoot moth control. Lake States Forest Expt. Sta. Tech. Note 542, 1 p. (Processed.)

JDOLF, PAUL O.
1951. Red pine and the European pine shoot moth in southern Michigan. Mich. Acad. Sci., Arts, and Letters Papers (1949 meeting) 35: 61-67, illus.

:HMIEGE, D. C.
1959. The pine root collar weevil. U. S. Forest Serv. Forest Pest Leaflet 39, 4 pp., illus.

_____ and ANDERSON, G. W.
* 1959. The forest insect and disease situation, Lake States, 1958. Lake States Forest Expt. Sta., Sta. Paper 70, 18 pp., illus. (Processed.) (A "situation" review is published annually.)

SECREST, H. C.
* 1944. Damage to red pine and jack pine in the Lake States by the Saratoga spittlebug. Jour. Econ. Ent. 37: 447-448.

_____, MacALONEY, H. J., and LORENZ, R. C.
1941. Causes of the decadence of hemlock at the Menominee Indian Reservation, Wisconsin. Jour. Forestry 39: 3-12, illus.

TALERICO, R. L.
* 1959. How to separate damage by the European pine shoot moth, the Zimmerman pine moth, and the pitch mass borer. Lake States Forest Expt. Sta. Tech. Note 571, 2 pp., illus. (Processed.)

WATERS, W. E., HELLER, R. C., and BEAN, J. L.
1958. Aerial appraisal of damage by the spruce budworm. Jour. Forestry 56: 269-276, illus.

WILSON, L. F.
* 1959. Branch "tip" sampling for determining abundance of spruce budworm egg masses. Jour. Econ. Ent. 52: 618-621, illus.

_____ and BEAN, J. L.
* 1959. A modified olfactometer. Jour. Econ. Ent. 52: 621-624, illus.

Disease

DERSON, GERALD W., and ANDERSON, RALPH L.
1959. The spread of oak wilt, 1955 to 1958. Lake States Forest Expt. Sta. Tech. Note 552, 1 p. (Processed.)

DERSON, NEIL A.
1959. Needle droop of red pine. Lake States Forest Expt. Sta. Tech. Note 549, 2 pp. (Processed.)

DERSON, RALPH L.
1953. Hypoxylon canker of aspen in the Lake States. Lake States Forest Expt. Sta. Tech. Note 400, 1 p. (Processed.)

_____ * 1956. Hypoxylon canker of aspen. U. S. Forest Serv. Forest Pest Leaflet 6, 3 pp., illus.

_____ and FRENCH, DAVID W.
* 1955. Evidence of races of Cronartium ribicola on Ribes. Forest Sci. 1: 38-39.

_____ and KAUFERT, F. H.
* 1959. Brooming response of black spruce to dwarfmistletoe infection. Forest Sci. 5: 356-364.

and SKILLING, D. D.
* 1955. Oak wilt damage--a survey in central Wisconsin. Lake States Forest Expt. Sta., Sta. Paper 33, 11 pp., illus. (Processed.)

_____ and CLIFFORD, E. D.
* 1956. Nursery root disease control by soil fumigation. Lake States Forest Expt. Sta. Tech. Note 449, 1 p. (Processed.)

BAXTER, DOW V., and HESTERBERG, GENE A.
* 1958. Fungi associated with decay in sugar maple, following logging injury. Lake States Forest Expt. Sta. Tech. Note 528, 2 pp. (Processed.)

BENZIE, JOHN W.
* 1958. A red pine plantation problem in Upper Michigan. Lake States Forest Expt. Sta. Tech. Note 524, 2 pp. (Processed.)

CHRISTENSEN, CLYDE M., ANDERSON, RALPH L., HODSON, A. C., and RUDOLF, PAUL O.
* 1951. Enemies of aspen. Lake States Forest Expt. Sta. Aspen Rpt. 22, 16 pp. (Processed.)

GODMAN, R. M.
* 1958. Changes in yellow birch top-dying, Upper Michigan, 1954-1957. Lake States Forest Expt. Sta. Tech. Note 527, 2 pp., illus. (Processed.)

GUILKEY, PAUL C., RUDOLPH, VICTOR J., and SHEPPARD, GEORGE.
1958. Effects of sweetfern rust on the growth of young jack pine in nor ern Lower Michigan. Jour. Fores 56: 900-903.

HESTERBERG, GENE A.
* 1957. Deterioration of sugar maple fol ing logging damage. Lake States Forest Expt. Sta., Sta. Paper 51 58 pp., illus. (Processed.)

KING, D. B.
* 1958. Incidence of white pine blister infection in the Lake States. L States Forest Expt. Sta., Sta. P 64, 12 pp., illus. (Processed.)

SCHMIEGE, D. C., and ANDERSON, G. W.
* 1959. The forest insect and disease si tion, 1958. Lake States Forest Sta., Sta. Paper 70, 18 pp., ill (Processed.) (A "situation" rev is published annually.)

SKILLING, D. D.
* 1959. Maple blight--a new fight. Amer Forests 65(5): 20-21, 53-55, ill

VAN ARSDEL, E. P., and NELSON, LEITON E.
* 1959. Blister rust spread is general i north, local in south Wisconsin during 1958. Lake States Forest Expt. Sta. Tech. Note 572, 2 pp. (Processed.)

Fire

CROSBY, JOHN S.
* 1949. Forest fire burning conditions in the Lake States. Lake States Forest Expt. Sta., Sta. Paper 16, 17 pp., illus. (Processed.)

DICKERMAN, M. B.
1958. Fire research in the Lake States. U. S. Forest Serv., R-9 Fire Meeting Proc. (1958): 17-21, 6 charts. (Mimeo.)

LaMOIS, LOYD M.
* 1956. Pine plantations offer fire protection problems in Lake States. Lake States Forest Expt. Sta. Tech. Note 462, 2 pp. (Processed.)

_____ 1957. Fire history and the present situation in northern woods. Timber Producer 13(4): 16-18, illus.

_____ * 1958. Fire fuels in red pine plantatic Lake States Forest Expt. Sta., S Paper 68, 19 pp., illus. (Proce ed.)

LeBARRON, R. K.
1940. The role of forest fires in the production of black spruce. Mir Acad. Sci. Proc. (1939 meeting) 10-14.

McCULLEY, ROBERT D.
1958. Use of fire in forest management U. S. Forest Serv., R-9 Fire Mee Proc. (1958): 43-49. (Mimeo.)

MITCHELL, J. A.
1928. Forest fires in Minnesota. Minn State Forest Serv. Bull., 74 pp. illus.

TCHELL, J. A.
1952. The Lake States burning index meter. U. S. Forest Serv. Fire Control Notes 13(3): 7-11, illus.

1953. Burning index ratings in fire control planning. Lake States Forest Expt. Sta., Sta. Paper 28, 13 pp., illus. (Processed.)

1954. Forest-fire control in the Lake States. Soc. Amer. Foresters Proc. 1954: 163-166, illus.

1954. Lake States forest fire damage tables for young second-growth stands. Lake States Forest Expt. Sta. Misc. Rpt. 27, 6 pp. (Processed.)

1954. Rating the effectiveness of forest fire protection. Jour. Forestry 52: 183-185, illus.

* 1954. Some thoughts on forest fire damage appraisal. Lake States Forest Expt. Sta. Misc. Rpt. 29, 4 pp. (Processed.)

_____ and LeMAY, NEIL.
1952. Forest fires and forest-fire control in Wisconsin (A historical record of forest protection activities in Wisconsin). Wis. Conserv. Dept., 75 pp., illus.

_____ and RICHMAN, H. W.
* 1936. Probability of rainfall during the fire season in the Lake States region. Lake States Forest Expt. Sta., unpaged, 21 charts. (Processed.)

_____ and ROBSON, D.
1950. Forest fires and forest fire control in Michigan. Mich. Dept. Conserv., 82 pp., illus.

List of Publications, 1959

Lake States Forest Experiment Station

General Forestry

Kobs, Harry W., and Chase, Clarence D. INCREASING EFFICIENCY OF PARALLAX BAR WITH ZEISS MIRROR STEREOSCOPE. Photogram. Engin. 25(1): 102, illus. 1959.

(Suggests a combination of several instruments to facilitate fast, accurate stereoscopic measurements.)

* Lake States Forest Experiment Station. ANNUAL REPORT, 1958. 76 pp., illus. (Processed.) 1959.

(Describes briefly the new projects and the progress on established projects during 1958.)

Regeneration, Stand Improvement, and Harvest Cuttings

* Arend, John L. AIRPLANE APPLICATION OF HERBICIDES FOR RELEASING CONIFERS. Jour. Forestry 57: 738, 740, 742, 744-745, 747-749. 1959.

(Developments in herbicidal spraying with aircraft for conifer release are brought together. Application of available knowledge is discussed and items still needing research attention are mentioned. Importance of competent aircraft operators is stressed.)

* Benzie, John W. SMALL TRACTORS, GROUND SKIDDING REDUCE TREE DAMAGE IN SELECTION HARVEST. The Timberman 60(11): 42, 43, 54, illus. 1959.

(Cutting an old-growth northern hardwood stand from 132 square feet of basal area to 70 square feet per acre in trees 10 inches d.b.h. and larger caused felling injuries on 5 percent of the residual trees. Skidding injuries were smaller and fewer where small equipment was used.)

* _____ SUGAR MAPLE AND YELLOW BIRCH SEED DISPERSAL FROM A FULLY STOCKED STAND OF MATURE NORTHERN HARDWOODS IN THE UPPER PENINSULA OF MICHIGAN. Lake States Forest Expt. Sta. Tech. Note 561, 1 p. (Processed.) 1959.

(The dispersal of seed from old-growth sugar maple and yellow birch trees at the Upper Peninsula Experimental Forest indicates that an adequate amount of seed can be expected for at least 5 chains in all directions during good seed years. Sugar maple seed is nearly all on the ground before snowfall, but most of the yellow birch seed falls on the snow.)

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* Available for distribution.

* _____ and Cross, Robert L. HEAVY THINNING INCREASES TREE SIZE AND YIELD IN AN UPPER MICHIGAN NORTHERN HARDWOOD POLE STAND. Lake States Forest Expt. Sta. Tech. Note 560, 2 pp. (Processed.) 1959.

(Removing one-third of the volume by cutting the poorer trees in a young northern hardwood pole stand did not appreciably change the net growth per acre during the first 9 years. The growth, however, was concentrated on fewer and better trees, and the thinning utilized many trees that otherwise might have been lost to mortality.)

* Conover, D. F., and Ralston, R. A. RESULTS OF CROP-TREE THINNING AND PRUNING IN NORTHERN HARDWOOD SAPLINGS AFTER NINETEEN YEARS. Jour. Forestry 57: 551-557, illus. 1959.

(Results in 1957 from noncommercial crop-tree thinnings made in 1938 and 1946 in a northern hardwood sapling stand showed a definite advantage in board-foot volume growth for plots with the widest crop-tree thinning radius. Crop-tree mortality was less on the thinned plots, but forking was more frequent.)

* Heinselman, M. L. NATURAL REGENERATION OF SWAMP BLACK SPRUCE IN MINNESOTA UNDER VARIOUS CUTTING SYSTEMS. U. S. Dept. Agr. Prod. Res. Rpt. 32, 22 pp., illus. 1959.

(Cutting experiments on the Big Falls Experimental Forest point toward even-aged management for swamp black spruce. Clear cutting in strips or patches, combined with slash burning or removal, are effective approaches because they eliminate overstory competition, provide a seed source, and expose as much good seedbed as possible.)

* Roe, Eugene I. DETERMINING MINIMUM AMOUNTS OF HERBICIDE NEEDED FOR AERIAL BRUSH CONTROL. Weeds 7: 178-183, illus. 1959.

(Describes the equipment and technique used in northern Minnesota to determine the minimum amounts of herbicide in terms of pounds and volume of solution per acre needed to control brush of different species and densities.)

* Rudolf, Paul O. 1958 FOREST TREE SEED CROP POOR IN THE LAKE STATES. Lake States Forest Expt. Sta. Tech. Note 565, 2 pp. (Processed.) 1959.

(Seed crops for the principal forest tree species are listed in percentage of full crops for northern Minnesota, northeastern Wisconsin, central Upper Michigan, Lower Michigan, and north-central North Dakota. The pines in general had poor seed crops.)

_____ REVIEW OF "CONIFERS: SOUTH AFRICAN METHODS OF CULTIVATION" BY W. E. HILEY. 123 pp., illus. London. 1959. Jour. Forestry 57: 931, 934. 1959.

* Scholz, Harold F. FURTHER OBSERVATIONS ON SEEDBED SCARIFICATION SHOW BENEFITS TO NORTHERN RED OAK WERE TEMPORARY. Lake States Forest Expt. Sta. Tech. Note 555, 2 pp. (Processed.) 1959.

(Reproduction counts made 7 years after the soil had been scarified in a well-stocked mixed oak forest showed no substantial

difference in the number of northern red oak seedlings per acre on treated and untreated plots. Thus the favorable 2 to 1 ratio for scarification observed at the end of the second growing season had all but disappeared 5 years later. The reasons for this retrogression have not been fully determined.)

* _____ and Trenk, Fred B. SIMPLE MEASURES CAN IMPROVE WISCONSIN'S FARM WOODLANDS: THE MIXED OAK TYPE. Lake States Forest Expt. Sta. Tech. Note 559, 2 pp. (Processed.) 1959.

(Six improvement cuttings removed 45,000 board feet, net scale, of logs and about 200 cords of rough wood from the 64-acre Dundee Timber Harvest Forest during the first 10-year cutting cycle. The sawtimber volume at the end of the period was 21 percent greater than at the beginning, and the quality of the stand was better because of removal of the poorer trees.)

* Skilling, D. D. GROWTH OF SWAMP CONIFERS FOLLOWING PARTIAL CUTTING. Lake States Forest Expt. Sta., Sta. Paper 71, 10 pp., illus. (Processed.) 1959.

(A growth study of the first 10-year period following partial cutting of a swamp conifer stand showed total production in both cords and basal area was greatest for those plots with the heaviest residual stand density (about 180 square feet of basal area). Wind losses due to partial cutting were negligible.)

* _____ PRUNING HARDWOODS IMPROVES QUALITY AND SHOWS LITTLE EVIDENCE OF FOSTERING DECAY. The Timberman 60(5): 64-66, illus. 1959.

(Results of several hardwood pruning studies indicate that hardwood pruning is a practical method of improving timber quality.)

* _____ RESPONSE OF YELLOW BIRCH TO ARTIFICIAL PRUNING. Jour. Forestry 57: 429-432, illus. 1959.

(Ten-year results show that yellow birch will respond favorably to artificial pruning. Pruning to 50 percent of total height had no effect on diameter growth. Small wounds under 2.0 inches healed rapidly with no evidence of decay. However, where large branches were not pruned flush with the bark, ingrown bark developed during healing; this indicated the importance of careful flush pruning.)

* Stoeckeler, J. H., and Skilling, D. D. DIRECT SEEDING AND PLANTING OF BALSAM FIR IN NORTHERN WISCONSIN. Lake States Forest Expt. Sta., Sta. Paper 72, 22 pp., illus. (Processed.) 1959.

(Trials in northeastern Wisconsin indicate the conditions required for successful direct seeding and planting of balsam fir. In general, seeding success was poor and planting results favorable. In many instances white spruce gave better planting results than did balsam fir.)

Tree Improvement

Larson, Philip R. REVIEW OF "THE PHYSIOLOGY OF FOREST TREES" EDITED BY KENNETH V. THIMANN, WILLIAM B. CRITCHFIELD, AND MARTIN H. ZIMMERMAN. 678 pp., illus. New York. 1958. Jour. Forestry 56: 916-917. 1958.

_____ THE TRANSITION OF EARLYWOOD TO LATEWOOD IN PINUS RESINOSA SEEDLINGS. Internatl. Assoc. Wood Anatomists News Bul. 1959(1): 3-4. 1959.

(Presents a brief summary of an experiment which tested the hypothesis that summerwood development is related to the cessation of terminal height growth and bud set.)

* Nienstaedt, Hans. THE EFFECT OF ROOTSTOCK ACTIVITY ON THE SUCCESS OF FALL GRAFTING OF SPRUCE. Jour. Forestry 57: 828-832, illus. 1959.

(Results of fall grafting experiments with white spruce show that, while rootstock activity at the time of grafting has little effect on survival and growth of the grafts, the right combination of chilling and daylength is essential. Scheduling after grafting is discussed in detail.)

_____ FALL GRAFTING OF SPRUCE AND OTHER CONIFERS. Plant Propagators Soc. Proc. 1958: 98-104. 1959.

(Briefly discusses the grafting of 10 species of spruce during September and October. By exposing the grafts to a combination of controlled daylength and low temperature, good results can be obtained with most species. Grafting of red and white pine in the fall is also discussed.)

_____ FOREST TREE IMPROVEMENT AT THE NORTHERN INSTITUTE OF FOREST GENETICS. In Proc. of Com. on Forest Tree Breeding in Canada (Sixth Meeting), Part II, 1958: Q-13-16. 1959.

(Describes briefly some results in tree improvement and physiology and outlines the more important current work.)

* Rudolf, Paul O. A BASIS FOR FOREST TREE SEED COLLECTION ZONES IN THE LAKE STATES. Minn. Acad. Sci. Proc. 24 (1956 Meeting): 20-28, illus. 1959.

(Seed collection zones previously proposed for the Lake States are reviewed and their differences pointed out. New zones based on a summation of normal daily temperatures per year above 50° F. and mean January temperature are proposed. Development of 119 sources of red pine 20 years after planting showed agreement with these zones.)

* _____ FOREST TREE IMPROVEMENT RESEARCH IN THE LAKE STATES. Lake States Forest Expt. Sta., Sta. Paper 74, 56 pp. (Processed.) 1959.

(Gives brief reports on 113 forest tree improvement research projects conducted by 11 agencies in the Lake States. Includes indexes by genera, research workers, and cooperators.)

_____ THE LAKE STATES FOREST TREE IMPROVEMENT COMMITTEE; ITS PURPOSE AND ACTIVITIES. In Proc. of Com. on Forest Tree Breeding in Canada (Fifth Meeting), Part II, 1957: N-1-4. (Processed.) 1959.

(Brief account of Lake States Forest Tree Improvement Committee covering its organization, membership, purposes, subcommittee activities, newsletter, and publications.)

* _____ SEED PRODUCTION AREAS FOR THE LAKE STATES: GUIDELINES FOR THEIR ESTABLISHMENT AND MANAGEMENT. Lake States Forest Expt. Sta., Sta. Paper 73, 16 pp., illus. (Processed.) 1959.

(Suggests standards and procedures for establishing seed production areas in the Lake States for red pine, jack pine, white pine, white spruce, and black spruce stands.)

_____ and Ochsner, H. E. REGISTERING AND MARKING SELECTIONS IN THE LAKE STATES; A REPORT OF A SUBCOMMITTEE OF THE LAKE STATES FOREST TREE IMPROVEMENT COMMITTEE. U. S. Forest Serv., No. Central Region, 10 pp. (Processed.) 1959.

(Recommends methods and forms for reporting superior or unusual forest trees in the Lake States. Includes a regional list of registers. Suggests methods for marking selected superior trees.)

Soils and Water

* Bay, Roger R. AN INEXPENSIVE SOIL TUBE JACK. Soil Sci. 88: 303-304, illus. 1959.

(An automobile bumper jack was modified to use as a puller jack for extracting soil sampling tubes. The modified jack cost about one-fifth the price of a commercial puller jack and soil tube grip.)

* Godman, R. M. ARE WATER TABLE LEVELS AN IMPORTANT FACTOR IN THE MANAGEMENT OF YELLOW BIRCH? Mich. Acad. Sci., Arts, and Letters Papers 44: 183-190, illus. 1959.

(Discusses the relationship of ground water levels with cover type association, and their influence on regeneration and diameter growth of yellow birch in Upper Michigan. Considers extended period of high water levels as a factor in the extensive top-dying of yellow birch in 1954.)

Sartz, Richard S. FORESTS AND WATER: A TALE OF TWO WATERSHEDS. Wis. Acad. Rev. 6: 55-58, illus. (Processed.) 1959.

(How forests minimize floods and erosion is told by describing what happens when both a forested and a bare watershed are hit by a heavy rain.)

* Stoeckeler, J. H. TRAMPLING BY LIVESTOCK DRASTICALLY REDUCES INFILTRATION RATE OF SOIL IN OAK AND PINE WOODS IN SOUTHWESTERN WISCONSIN. Lake States Forest Expt. Sta. Tech. Note 556, 2 pp., illus. (Processed.) 1959.

(Livestock trampling reduced infiltration by 93 percent as measured by 3-inch cylinders.)

* Striffler, W. D. EFFECTS OF FOREST COVER ON SOIL FREEZING IN NORTHERN LOWER MICHIGAN. Lake States Forest Expt. Sta., Sta. Paper 76, 16 pp., illus. (Processed.) 1959.

(A study of soil freezing under four forest types showed that concrete frost occurred most often under dense red pine plantations, less often under open red pine plantations, and rarely under oak and northern hardwoods; frost depth decreased in the same order. Frost type under the open plantations and the oak was primarily granular or honeycomb. Frost type and depth were also related to humus type and depth.)

* Urie, Dean H. PATTERN OF SOIL MOISTURE DEPLETION VARIES BETWEEN RED PINE AND OAK STANDS IN MICHIGAN. Lake States Forest Expt. Sta. Tech. Note 564, 2 pp., illus. (Processed.) 1959.

(Depletion of soil moisture by 25-year-old red pine plantations exceeded that under native oak forests during the early part of the growing season. After full leaf development of the oaks, the level of soil moisture under them was depleted rapidly until soils under both cover types were near wilting point by early August. Total evapotranspiration for both cover types was similar.)

* Weitzman, Sidney, and Bay, Roger R. SNOW BEHAVIOR IN FORESTS OF NORTHERN MINNESOTA AND ITS MANAGEMENT IMPLICATIONS. Lake States Forest Expt. Sta., Sta. Paper 69, 18 pp., illus. (Processed.) 1959.

(Snow accumulation and melt patterns were observed under three major cover types--red pine, aspen, and black spruce. The effects of timber management practices such as thinning, cutting methods, type conversion, and plantation management are discussed in terms of snow behavior.)

Forest Insects

* Anderson, Gerald W., and Schmiege, Donald C. THE FOREST INSECT AND DISEASE SITUATION, LAKE STATES, 1958. Lake States Forest Expt. Sta., Sta. Paper 70, 18 pp., illus. (Processed.) 1959.

(A cooperative report based on surveys conducted by Federal, State, and private agencies in 1958.)

* Bean, James L. FRASS SIZE AS AN INDICATOR OF SPRUCE BUDWORM LARVAL INSTARS. Ent. Soc. Amer. Annals 52: 605-608, illus. 1959.

(Frass size can be used effectively to classify larval instars. The frass collected in the field can be used as an index of the percent of larvae in each instar at the time the collection is made.)

* Haynes, Dean L. DORSAL CONTACT TOXICITY OF SIX INSECTICIDES TO WINTERING LARVAE OF THE EUROPEAN PINE SHOOT MOTH. Jour. Econ. Ent. 52: 588-590. 1959.

(Six organic insecticides were tested against the overwintering larvae of the European pine shoot moth. No significant mortality was obtained with DDT, chlordane, or BHC at any concentrations used. Malathion, Thimet O, O-diethyl S-(ethylthio) methyl phos-

phorodithioate, and dimethoate produced mortality at all concentrations used.)

Heller, R. C., Bean, J. L., and Knight, F. B. AERIAL SURVEYS OF BLACK HILLS BEETLE INFESTATIONS. Rocky Mtn. Forest and Range Expt. Sta., Sta. Paper 46, 8 pp., illus. (Processed.) 1959.

(Presents a method for surveying Black Hills beetle infestations from the air. Estimates of the number of trees killed the preceding year can be obtained by visual means or color photographs. The ratio between previously attacked and currently infested trees is obtained from ground checks.)

* Miller, William E. PRELIMINARY STUDY OF EUROPEAN PINE SHOOT MOTH PARASITISM IN LOWER MICHIGAN. Jour. Econ. Ent. 52: 768-769. 1959.

(Parasitism of the European pine shoot moth by native parasites in two shoot moth problem areas in Michigan is shown to be slight. It would probably be worthwhile to import parasites from Europe, where the number of different kinds of parasites affecting the shoot moth is greater, as is their importance in suppressing this insect.)

* _____ A UNIQUE NEW NORTH AMERICAN SPECIES OF PINE CONE FEEDING LASPEYRESIA RELATED TO L. INGENS HEINRICH. Fla. Ent. 42(3): 131-134, illus. 1959.

(A brightly colored pine cone moth new to science is described and named. It affects cones of several pine species in the Southeast.)

* _____ and Heikkenen, H. J. THE RELATIVE SUSCEPTIBILITY OF EIGHT PINE SPECIES TO EUROPEAN PINE SHOOT MOTH ATTACK IN MICHIGAN. Jour. Forestry 57: 912-914, illus. 1959.

(Ratios of number of insects to number of shoots on each of eight pine species were compared near the end of the shoot moth generation. Virginia, pitch, jack, and eastern white pines had very low ratios and were thus rated as slightly susceptible. Ponderosa, Austrian, and Scotch pine were in the middle range. Red pine had the highest ratio in the study and was therefore rated high in susceptibility.)

* Schmiege, D. C. THE PINE ROOT COLLAR WEEVIL. U. S. Forest Serv., Forest Pest Leaflet 39, 4 pp., illus. 1959.

(The life stages of the root collar weevil and the damage it causes are described and illustrated. Prevention of damage through silvicultural practices and direct control with chemicals are discussed.)

_____ THE PINE ROOT COLLAR WEEVIL--WATCH FOR THIS PEST IN YOUR PINE PLANTATIONS. The Timber Producer 15(1): 10-11, illus. 1959.

(Describes damage, life history, and habits of an important plantation insect. Possibilities of preventing damage and controlling the insect are discussed.)

* Talerico, Robert L. HOW TO SEPARATE DAMAGE BY THE EUROPEAN PINE SHOOT MOTH, THE ZIMMERMAN PINE MOTH, AND THE PITCH MASS BORER. Lake States Forest Expt. Sta. Tech. Note 571, 2 pp., illus. (Processed.) 1959.

(Differentiates damage caused by these insects and gives a brief account of their life cycles.)

* Wilson, Louis F. BRANCH "TIP" SAMPLING FOR DETERMINING ABUNDANCE OF SPRUCE BUDWORM EGG MASSES. Jour. Econ. Ent. 52: 618-621, illus. 1959.

(The tips of shoots are separated from the branch, and egg masses are counted; the number on the tips must be increased by 16 percent to obtain the total number on the branch. Time saved by this technique ranges from 25 to 40 percent. The technique is not feasible for severely or completely defoliated branches.)

* _____ and Bean, James L. A MODIFIED OLFACTOMETER. Jour. Econ. Ent. 52: 621-624, illus. 1959.

(This olfactometer differs from previous models in the materials used and technical modifications. The insect test cage was made of lucite and shaped to eliminate dead airspaces and intermixing of air. The influent ports, valve system, and air-flow controls were also modified.)

Forest Diseases

* Anderson, Gerald W., and Anderson, Ralph L. THE SPREAD OF OAK WILT, 1955 TO 1958. Lake States Forest Expt. Sta. Tech. Note 552, 1 p. (Processed.) 1959.

(The 1958 rate of establishment of new oak wilt infection centers increased over that of the previous 3 years, while the radial spread on existing centers decreased.)

* _____ and Schmiege, Donald C. THE FOREST INSECT AND DISEASE SITUATION, LAKE STATES, 1958. Lake States Forest Expt. Sta., Sta. Paper 70, 18 pp., illus. (Processed.) 1959. (Also listed under Forest Insects.)

(A cooperative report based on surveys conducted by Federal, State, and private agencies in 1958.)

* Anderson, Neil A. NEEDLE DROOP OF RED PINE. Lake States Forest Expt. Sta. Tech. Note 549, 2 pp. (Processed.) 1959.

(Eighty-nine percent of the sample trees observed in a north-central Minnesota red pine plantation were affected by needle droop. Dead terminal buds were present on 47 percent of this sample.)

Anderson, Ralph L. MAPLE BLIGHT, A NEW PROBLEM IN THE LAKE STATES. Northeast. Logger 7(11): 28-29, illus. 1959.

(Severe mortality in maple stands of all size classes occurred in two areas in northeastern Wisconsin during 1957. Considerable effort is being expended to learn the cause of this mortality.)

* _____ and Kaufert, Frank H. BROOMING RESPONSE OF BLACK SPRUCE TO DWARFMISTLETOE INFECTION. Forest Sci. 5: 356-364, illus. 1959.

(Describes the variations in host reaction that result in forming three types of witches'-brooms. Relates broom form to host vigor and age. Discusses evidence for growth reduction and mortality caused by the disease.)

* Godman, R. M. WINTER SUNSCALD OF YELLOW BIRCH. Jour. Forestry 57: 368-369, illus. 1959.

(Describes the position, extent, and development of stem injury to yellow birch saplings and poles in well-stocked northern hardwood stands. Associates a sudden temperature change on Feb. 16, 1948, as the probable time of occurrence.)

* Skilling, D. D. MAPLE BLIGHT, A NEW FIGHT. Amer. Forests 65(5): 20, 21, 53-55, illus. 1959.

(Describes the progress made on maple blight investigations since the blight was reported in 1957.)

* Thorne, Harry W., and Stone, Robert N. DEFECT IN WISCONSIN TIMBER. Lake States Forest Expt. Sta. Tech. Note 568, 2 pp., illus. (Processed.) 1959.

(Defect as a percent of volume is shown for major species in Wisconsin.)

Van Arsdel, E. P. CLIMATIC RELATIONS OF WHITE PINE BLISTER RUST AND ITS CONTROL. In Research in Wisconsin, Wis. Conserv. Dept., pp. 56-57. (Processed.) 1959.

(Summarizes progress on studies of the influence of climatic factors on blister rust prevalence and distribution.)

* _____ and Nelson, Leiton E. BLISTER RUST SPREAD IS GENERAL IN NORTH, LOCAL IN SOUTH WISCONSIN DURING 1958. Lake States Forest Expt. Sta. Tech. Note 572, 2 pp. (Processed.) 1959.

(Describes the pattern of rust development on Ribes and its spread to pine during 1958 as related to geographic location and weather conditions.)

Wildlife

Krefting, L. W. SURVIVAL AND GROWTH OF SOME WILDLIFE COVER PLANTINGS IN MINNESOTA. Univ. Minn., Minn. Forestry Note 79, 2 pp. (Processed.) 1959.

(The study shows that large wilding balsam fir and black and white spruce can be transplanted successfully. For wildlife use, the cover plantings should be at least 1/10 acre and the trees should be spaced 4x4 feet. White-tailed deer, moose, ruffed grouse, snowshoe hare, and red squirrels have made use of them over the past 24 years, especially during the winter months.)

McCulley, Robert D. MANAGEMENT FOR WOOD AND WILDLIFE. The Conserv. Volunteer 22(130): 49-52, illus. 1959.

(Relationship between the forest and wildlife are reviewed. Close correlation of timber and wildlife management is suggested.)

Forest Economics

* Lundgren, Allen L. COSTS OF MARKING BLACK SPRUCE FOR CUTTING IN NORTHERN MINNESOTA. Lake States Forest Expt. Sta. Tech. Note 546, 2 pp. (Processed.) 1959.

(Marking costs per cord of black spruce varied widely with the cutting method used, ranging from about 2 to 20 percent of the stumpage price. It took almost twice as long to mark a cord under the shelterwood system and nearly five times as long under the light selection cut system where individual trees were marked, as under the clearcut system where area boundaries were designated.)

* Stoeckeler, J. H., Trenk, F. B., and Strothman /Strothmann/, R. O. TIMBER GROWTH AND LABOR OPPORTUNITIES FOR SUSTAINED HARVEST CUTS--ARGONNE TIMBER HARVEST FOREST. Univ. Wis., Forestry Res. Note 46, 2 pp. (Processed.) 1959.

(Annual harvest cuts approximating the annual growth were made for 8 successive years on a northern hardwoods farm forestry forty. During this period 42.9 MBM of sawlogs, 33.8 cords of softwood pulpwood, and 125.8 cords of hardwood fuelwood were harvested. This required 1,196 man-hours of labor, of which 63 percent was for felling and bucking, and the remainder for skidding by horse and tractor.)

* _____, _____, and _____ WAGE INCOME FROM IMPROVEMENT HARVEST CUTS--ARGONNE TIMBER HARVEST FOREST. Univ. Wis., Forestry Res. Note 47, 2 pp. (Processed.) 1959.

(Annual harvest cuts approximating the annual growth were made for 8 successive years on a northern hardwoods farm forestry forty. The net income per year was $248, or an average of $1.66 per man-hour of labor. This compares favorably with the per-hour wages that the average farmer in northern Wisconsin earns from his regular farming operation.)

* Sutherland, Charles F., and Tubbs, Carl. INFLUENCE OF OWNERSHIP ON FORESTRY IN SMALL WOODLANDS IN CENTRAL WISCONSIN. Lake States Forest Expt. Sta., Sta. Paper 77, 21 pp., illus. (Processed.) 1959.

(Describes characteristics of owners of small woodlands, objectives of forest land use, frequency of timber harvests, and reasons owners gave for taking part or not taking part in forestry programs. Characteristics which most often indicated relationship with owner objectives and practices were occupation, size of forest tract, and age. Although few owners now practice forestry, circumstances seem favorable for more intensive forestry promotion.)

Timber Resource and Production Statistics

* Essex, Burton L. PRODUCTION OF MISCELLANEOUS TIMBER PRODUCTS--LAKE STATES, 1958. Lake States Forest Expt. Sta. Tech. Note 573, 2 pp. (Processed.) 1959.
(Reports the amount of timber cut for various products.)

_____, Chase, Clarence D., and Horn, Arthur G. TIMBER RESOURCES, SOUTHEASTERN BLOCK, LOWER PENINSULA, MICHIGAN, 1955. Mich. Dept. Conserv., 52 pp., illus. (Processed.) 1959.
(Presents data for forest area, timber volume, growth, allowable cut, and timber cut for the Block, and forest area and timber volumes for each county.)

* Findell, Virgil E., and Pfeifer, Ray E. COMMERCIAL FOREST LAND IN MICHIGAN BY FOREST TYPE AND COUNTY. Lake States Forest Expt. Sta. Tech. Note 547, 2 pp. (Processed.) 1959.
(Lists the commercial forest area by type for each county.)

* _____ and _____ NET TIMBER VOLUME IN MICHIGAN BY SPECIES GROUP AND COUNTY. Lake States Forest Expt. Sta. Tech. Note 548, 2 pp. (Processed.) 1959.
(Presents net sawtimber and total volume by species or species group for each county.)

Horn, A. G.
* LAKE STATES PULPWOOD PRODUCTION AND IMPORTS DECLINE IN 1958. Lake States Forest Expt. Sta. Tech. Note 558.
* MINE-TIMBER PRODUCTION DECLINES AS MORE SUBSTITUTES ARE USED AND LESS ORE IS MINED, LAKE STATES, 1958. Lake States Forest Expt. Sta. Tech. Note 570.
* VENEER LOG PRODUCTION DECLINES SHARPLY IN LAKE STATES AS RESULT OF MILL CLOSURES, 1958. Lake States Forest Expt. Sta. Tech. Note 567.
(Each of these 2-page Notes--processed, 1959--shows production by species and State and imports from other States and Canada. Pulpwood Note shows movement between States in region.)

* _____ WISCONSIN CHRISTMAS TREE HARVEST ESTIMATED AT NEARLY 1-1/3 MILLION TREES, 1957. Lake States Forest Expt. Sta. Tech. Note 553, 2 pp., illus. (Processed.) 1959.
(Shows Christmas tree production by species and ownership class in each forest survey district.)

* Stone, Robert N. ESTABLISHED FOREST PLANTATIONS IN NORTHERN LOWER MICHIGAN, 1957. Lake States Forest Expt. Sta. Tech. Note 551, 2 pp., illus. (Processed.) 1959.
(Shows the area of established plantations in northern Lower Michigan by owner, type, stand-size class, and density.)

* _____ and Thorne, Harry W. FOREST AREA IN WISCONSIN COUNTIES. Lake States Forest Expt. Sta. Tech. Note 554, 2 pp. (Processed.) 1959.
(Shows the area of commercial forest land and the proportion of land area occupied by forest in each county.)

* _____ and _____ TIMBER VOLUME IN WISCONSIN COUNTIES. Lake States Forest Expt. Sta. Tech. Note 569, 2 pp. (Processed.) 1959.
(Shows timber volume by species and county.)

* Thorne, Harry W., and Stone, Robert N. COMMERCIAL FOREST LAND IN WISCONSIN COUNTIES BY FOREST TYPE. Lake States Forest Expt. Sta. Tech. Note 562, 2 pp. (Processed.) 1959.
(Shows commercial forest area by forest type and county.)

Thornton, Philip L., and Morgan, James T. THE FOREST RESOURCES OF IOWA. Central States Forest Expt. Sta., Forest Survey Release 22, 46 pp., illus. 1959.
(Presents forest statistics for Iowa and analyzes and interprets them. Timber growth is more than twice timber cut. Even so, growth could be increased substantially if stands were better stocked.)

Wisconsin Conservation Department and Lake States Forest Experiment Station.
FOREST RESOURCES OF TEN COUNTIES IN EAST CENTRAL WISCONSIN. Wis. Conserv. Dept., Forest Inventory Pub. 34, 48 pp., illus. (Processed.) 1958.
FOREST RESOURCES OF 13 COUNTIES IN SOUTHEASTERN WISCONSIN. Wis. Conserv. Dept., Forest Inventory Pub. 35, 54 pp., illus. (Processed.) 1959.
FOREST RESOURCES OF EIGHT COUNTIES IN WEST CENTRAL WISCONSIN. Wis. Conserv. Dept., Forest Inventory Pub. 36, 46 pp., illus. (Processed.) 1959.
FOREST RESOURCES OF EIGHT COUNTIES IN SOUTHWESTERN WISCONSIN. Wis. Conserv. Dept., Forest Inventory Pub. 37, 46 pp., illus. (Processed.) 1959.
(Each of these four reports presents forest area, timber volume, growth, timber cut, and allowable cut for the Block and for individual counties.)

Timber Utilization and Marketing

* Larson, Philip R. PREPARATION OF SMALL WOOD BLOCKS FOR PHOTOMICROGRAPHY. Stain Technol. 34: 155-156, illus. 1959.
(Describes a technique for bringing out the contrast between various wood elements for photomicrography by treating small wood blocks with levigated alumina.)

* Lohrey, Richard E. DEBARKING BIGTOOTH ASPEN WITH 2,4-D AMINE SALT. Lake States Forest Expt. Sta. Tech. Note 550, 2 pp. (Processed.) 1959.
(Undiluted or a 50-percent concentration of 2,4-D amine

applied in frills was nearly as effective a bark-loosening agent as sodium arsenite. Lesser concentrations of 2,4-D gave poor results and were inferior to bark applications of 2,4,5-T ester.)

* Marden, R. M., and Conover, D. F. DIAGRAMING TECHNIQUES FOR DESCRIBING TREE STEMS AND CROWNS. Jour. Forestry 57: 173-175, illus. 1959.

(Describes diagraming techniques used on the Argonne Experimental Forest in northern Wisconsin to test the effects of various cutting intensities and residual stocking levels on quality development of young northern hardwoods. Defect indicators are diagramed and photographed periodically to evaluate stem changes. The information will be valuable in forming marking guides for the management of young stands. Tree crowns are diagramed to measure changes in tree growth and stem defect development as related to crown size and competition.)

Neetzel, John R., and Kite, G. D. ANSWERS TO YOUR FENCING PROBLEMS. Farm Quart. 14(1): 64-67, 100+, illus. 1959.

(This article deals largely with new ideas in fence design and construction, with special emphasis on the mechanization of farm fencing through power driving of wood posts.)

_____ and Otis, C. K. ROSEMOUNT EXPERIMENT STATION TRIES NEW IDEAS IN ANIMAL SHELTER BUILDINGS. Farm and Home Sci. 16(2): 20-21, illus. 1959.

(Describes some of the principal features of a pole-type hog farrowing house, hog feeding buildings, and a large structure for research with turkeys. Some new ideas in insulated and ventilated pole buildings are discussed.)

Salzman, J. A., Sullivan, E. T., Neetzel, J. R., and Shiue, C. J. THE WATER-HOLDING CAPACITY OF WOOD CHIPS AS COMPARED WITH COMMON LIVESTOCK BEDDINGS. Univ. Minn., Minn. Forestry Note 69, 2 pp. (Processed.) 1958.

(This study compared the water-holding capacity of wood chips which have had limited use for livestock and poultry bedding, with that of straw and other bedding materials. Chips were somewhat inferior to straw but compared favorably with most bedding materials.)

* Stone, Robert N., and Chase, Clarence D. SAWTIMBER LOG GRADES IN WISCONSIN. Lake States Forest Expt. Sta. Tech. Note 563, 2 pp. (Processed.) 1959.

(Presents log grade distribution for several major Wisconsin species as determined by field study.)

* Ward, James C. AIR SEASONING OF WOOD REDUCES CHARCOAL PRODUCTION TIME. Lake States Forest Expt. Sta. Tech. Note 566, 2 pp., illus. (Processed.) 1959.

(The results of six experimental burns in a small charcoal

kiln showed that carbonization time for air-seasoned wood was about 40 percent less than for green wood.)

* _____ THE EFFECT OF TIME AND CARBONIZING TEMPERATURES ON QUALITY OF CHARCOAL FROM A CINDER-CONCRETE BLOCK KILN. Lake States Forest Expt. Sta. Tech. Note 557, 2 pp., illus. (Processed.) 1959.

(Charcoal produced in small cinder-concrete block kilns increases in volatile content from top to bottom of the charge because carbonization begins at the top and proceeds downward through the load. However, the composition of the total kiln yield is within the requirements for good-quality, domestic-grade charcoal.)

* Warner, John R., and Tubbs, Carl H. WOOD USE BY MANUFACTURING FIRMS IN MINNEAPOLIS AND ST. PAUL. Lake States Forest Expt. Sta., Sta. Paper 75, 30 pp., illus. (Processed.) 1959.

(Shows how and where lumber is procured and its uses, the lumber characteristics required, and how industry regards lumber presently used; outlines sampling methods for the study.)

TERRITORY SERVED BY THE

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